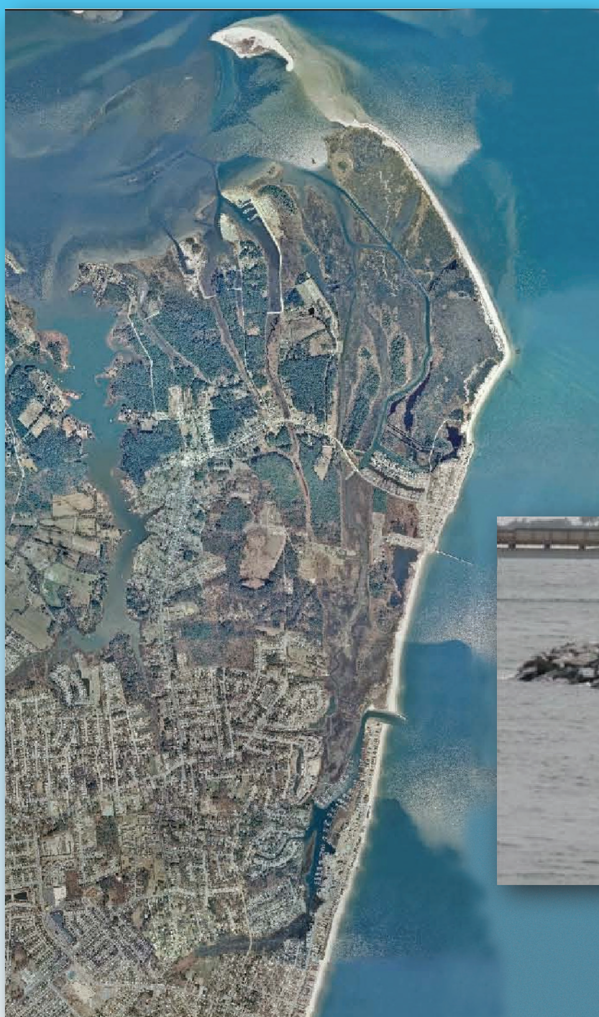
Hampton Beachfront and Storm Protection Management Plan



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A special recognition is offered to Tom Daniel, former City of Hampton employee and Director of both Parks and Recreation and General Services. Through his vision and leadership, comprehensive beachfront management planning was initiated in Hampton which resulted in the construction of the first full scale beach renourishment project at Buckroe Beach, as well as the pilot breakwater project in front of Buckroe Avenue and the innovative "geotube" dune project along Salt Ponds Public Beach.

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1.0 INTRODUCTION

1.1 Purpose

Beach and water fronting property are a major asset to any community. These properties, whether public or private, are typically associated with the highest real estate values, as well as the greatest recreational or “quality of life” benefits. Living along the shoreline, however, offers its challenges in terms of susceptibility to damages and flooding resulting from coastal storms. Therefore, it is in the community’s best interest from both an economic, as well as an aesthetic perspective, to preserve and maintain its beachfront assets through comprehensive management planning.

The primary goal for beach management planning along the Hampton shoreline is to develop strategies to reduce damages and property loss resulting from storm impacts and coastal flooding. A secondary, but important goal is to develop strategies to improve recreational benefits for citizens and visitors, as well as preserve and possibly enhance the existing natural resources.

This Plan is a culmination of numerous years of research, hydrodynamic modeling, citizen input, and monitoring efforts. Section 1.0 provides the history of management practices and a summary of the relevant studies utilized to develop this plan. Chapter 2 is dedicated to discussing the physical coastal processes that impact the shoreline (winds, waves, currents, tides and coastal storms). Chapter 3 presents the physiographic components of the shoreline and includes information on sediment transport, patterns of shoreline change, and longshore or littoral transport potential. Chapter 4 includes a complete summary of all practicable shoreline protection alternatives, as well as general cost estimates. Chapter 5 offers management planning recommendations for each reach of the shoreline based on the results of the modeling, hydrodynamic conditions and physiographic properties and Chapter 6 presents the modeling results of those strategies. The remaining sections are dedicated to plan recommendations and implementation.

The Hampton Beachfront Storm Protection and Management Plan is an update of earlier studies and recommendations produced as draft reports in 1988, 1999 and 2002. As a result, some implementation of those plan recommendations has already occurred including municipal sponsorship in the Hurricane and Storm Damage Reduction Project at Buckroe, beach renourishment at Salt Ponds as a “betterment” to the federal project, and construction of two breakwaters along the public beach at Buckroe.

1.2 Project Location

The primary sandy shoreline of Hampton, Virginia extends approximately 8.3 miles along the Chesapeake Bay and includes the sandy beaches from Fort Monroe at the southernmost extent to Northend or Factory Point at its northernmost point. The southern beaches, Fort Monroe, Buckroe Beach, Malo Beach and Salt Ponds Beach are separated from the northern beaches of White Marsh, Grandview, and Grandview Nature Preserve by Salt Ponds Inlet. Salt Ponds Inlet is a dredged and stabilized navigation channel, which provides recreational boat access between the Salt Ponds harbor area and the Chesapeake Bay. Figure 1-1 depicts the location of the Hampton shoreline and the primary boundaries of the study area for this management plan.

There are several public beaches along the Hampton shoreline. The beach at Buckroe is the most widely used and provides the most amenities including parking, restrooms, picnic facilities, a fishing pier, an amphitheater and lifeguard services. The community also developed a popular recreational playground area adjacent to the public beach. The public beach extends from just south of the Buckroe Fishing Pier to Pilot Avenue.

Salt Ponds public beach begins at the end of North First Street and extends to Salt Ponds Inlet. There is a public access, but limited public parking along North First Street. The third and largest public beach in Hampton is the Grandview Nature Preserve, which includes the beaches north of the private Grandview community. This is a passive recreational area. Parking is available, but public use is relatively low due to the lengthy walk to the beachfront. Northend Point or Factory Point is a popular boating destination and as a result much of the beach use is associated with recreational boating activities.

Several thousand feet of privately owned beaches are interspersed between the public areas. Thimble Shoals Court is located between Fort Monroe and the public beach at Buckroe. The private beach along Buckroe is referred to as Malo Beach and it is sited between the public beaches of Buckroe and Salt Ponds along North First Street. White Marsh is located just north of Salt Ponds Inlet and extends to Grandview. It is primarily privately owned and is currently undeveloped. The private shoreline along Grandview includes the area between the remnants of the Grandview Fishing Pier and the Grandview Nature Preserve. This section of shoreline is protected with a seawall and revetment and does not typically support a dry beach at high tide.

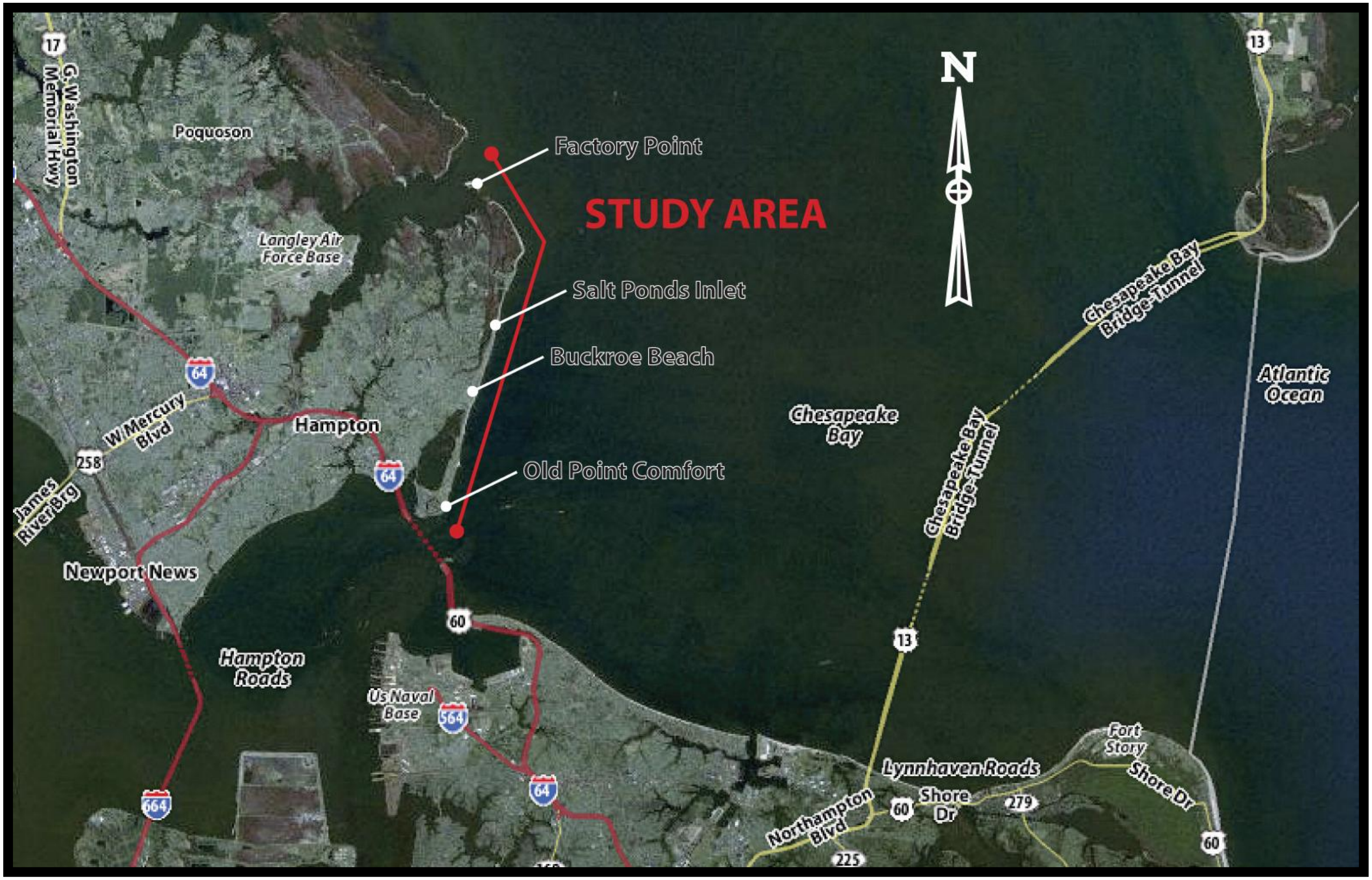


Figure 1-1: Site location and study limits for the Hampton Beachfront Management and Storm Protection Plan.

Ownership along the Hampton bayfront beaches poses unique management issues in terms of regulatory permits, continuity in project design and public funding for construction. Federal interests at Fort Monroe account for 29% of the beachfront ownership at the southern end of the primary study area, while the interspersed areas of private and public beaches account for 26% and 45% of the ownership, respectively.

Additional private sandy beaches exist throughout Hampton, the most notable at Strawberry Banks (currently owned by Hampton University), along Chesapeake Avenue and on the north side of Mill Creek. Other areas along the Hampton shoreline waterfront associated with the Hampton River, Back River, Harris Creek and Indian River Creek experience erosion and flooding, as well. While the primary focus of this report is for management of Hampton's bayfronting, sandy beaches, alternative strategies to protect property, reduce shoreline erosion and to enhance habitat are provided in Section 4 and will be applicable to those areas as well.

1.3 Background

Historically, both the public and private beaches along the City of Hampton have experienced erosion, particularly as a result of high tides and waves resulting from northeasters and tropical storms. The City recognized that its beaches were disappearing and in 1986 adopted the Beachfront Master Plan, which detailed the City's vision for improving the quality and public use of the shoreline. As a result, beach renourishment activities and other shoreline management strategies were initiated along the public beaches to provide storm protection and a recreational area for the community.

After the Ash Wednesday Storm of 1962, at least twenty timber groins were constructed along Buckroe Beach, Malo Beach, Salt Ponds Beach and a portion of White Marsh Beach. Later, four rock groins were constructed along Dog Beach at Fort Monroe to alleviate erosion. A timber bulkhead with a concrete cap was also constructed along the public beach at Buckroe during the late 1960's. Grandview experienced a similar history of shoreline protection. During the early 1960's, a bulkhead and at least one rock groin were constructed to protect the uplands. Later, various types of revetment were installed, hardening the majority of the Grandview shoreline.

In 1990, the first major beach renourishment project was constructed along Buckroe Beach. A reported volume of 224,000 cubic yards (cy) of sandy material were dredged from an offshore borrow area at Horseshoe Shoals and placed along the public shoreline. The design cross-section included a 50-ft wide beach at an elevation of approximately 7.5 ft mean low water (MLW) or NAVD. This design was estimated to protect the bulkhead and upland infrastructure from the impacts of a 10-year storm event. The 1990 project included between five and seven years of "advance maintenance" renourishment for a total construction width of almost 200 ft.

The 1990 renourishment project was monitored annually to evaluate its performance. In 1995, five years after construction, beach surveys showed that the northern portion of the project was smaller than its design width. To maintain the integrity of the overall project, a second renourishment project was constructed in 1996. Approximately 55,000 to 60,000 cy of sand were hydraulically placed on the beach between Buckroe Avenue and Pilot Avenue to extend the design width to 110 ft.

During the 1990's, the shoreline along the lower Chesapeake Bay experienced a greater storm frequency and higher tides than in the previous decade. As a result, the narrow strip of land referred to as Factory Point at the north end of the project was breached. In January and February of 1998, a pair of storms referred to as the "twin nor'easters" impacted the Hampton shoreline within a period of two weeks. The storm tides reached 6.04 ft and 6.58 ft above mean lower low water (MLLW) at the Sewells Point tide gage in Hampton Roads (4.39 ft and 4.93 ft NAVD). These tides were 3.49 ft and 4.02 ft above the average elevation of mean high water (MHW). The storms significantly eroded dunes and damaged homes along the shoreline. In particular, severe erosion along Salt Ponds threatened the shorefront homes and a 2,000 ft dune restoration project with a geotube core was constructed in July of 1998. Later during that same year, Hurricane Bonnie passed near Hampton Roads and then in the summer of 1999, two back-to-back hurricanes, Dennis and Floyd, elevated tide and wave levels again causing more beach erosion. The breach at Factory Point continued to widen.

In October of 2001, the first breakwater was constructed along the public beach at Buckroe in front of Buckroe Avenue. The design and location were based on recommendations provided in earlier studies.

On September 18, 2003, Hurricane Isabel devastated the Hampton shoreline causing significant flooding, beach erosion and wind damage throughout the municipality. The tide gage at Sewells Point registered a peak water level of 7.89 ft MLLW (6.24 ft NAVD), the second highest on record at that gage. The majority of the older homes in Grandview were condemned, while significant flooding occurred throughout Buckroe, Phoebus, Fort Monroe and other tidal areas throughout Hampton. The geotube dune project at Salt Ponds helped protect the upland structures, but over one third of the geotube was damaged requiring repair. The sandy beach and breakwater along the public beach at Buckroe continued to protect the bulkhead and uplands from wave impacts; however, flooding was extensive throughout the area.

The federal Hurricane and Storm Damage Reduction project was constructed along Buckroe Beach in February 2005. Although it did not qualify as a federal project, the City of Hampton included renourishment at Salt Ponds as a "betterment" to the federal project. Approximately 320,000 CY of sand were placed along the beach at Buckroe and 113,000 CY of sand were placed along the public beach at Salt Ponds.

In the fall/winter of 2005/2006, improvements were made to the south jetty at Salt Ponds Inlet. The timber structure was replaced with a vinyl sheetpile structure and it was lengthened. The jetty was constructed at the same height as the replaced structure. The inlet has continued to shoal requiring maintenance dredging every eighteen months to two years.

Due to concerns of increased flooding throughout Back River, a citizen's group was organized and appointed by the City of Hampton during the spring of 2007 to develop recommendations for improvements throughout the watershed. The primary recommendation was to restore and stabilize the breach at Factory Point and to improve navigation in Back River. Planning, design and permitting of the project took more than two years and construction was initiated in October of 2009. By April, 2010 more than 140,000 CY of sand was dredged from the shoal adjacent to the breach and constructed into a renourishment project to connect the island at Factory Point back to the Grandview Nature Preserve. Five breakwaters/sills were also built to stabilize the beach and the primary navigation channels were dredged and remarked to improve boating safety. At the beginning of construction, a major northeaster impacted the area in November, 2009. That storm yielded the third highest tide on record at Sewells Point and caused significant flooding throughout Hampton.

During the end of the breach restoration project (April, 2010), a second breakwater was constructed at the end of Point Comfort Avenue near the south end of the public beach at Buckroe. Repairs were also made to the original breakwater at that time. A third breakwater has been planned for construction at the end of Pilot Avenue in the spring of 2011.

Severe northeaster and tropical storm activity has continued to cause significant flooding and shoreline erosion along Hampton's beaches. The objective of this plan is to develop strategies to improve storm and flood protection, and improve or enhance recreational opportunities and habitat.

1.4 Previous Investigations

The "Hampton Beachfront Storm Protection and Management Plan" is the result of a phased approach to comprehensive shoreline management and is based on numerous previous and ongoing investigations. The following narrative briefly lists the reports and studies conducted along Hampton's beachfront.

<u>Shoreline Situation Report, City of Hampton, Virginia</u> (VIMS, 1975)

The purpose of this report was to provide a tool for future planning along the shoreline including the sandy beaches, as well as the marshes. This study divided the shoreline into segments which were classified in terms of physiography, land use and ownership. The report also discussed shoreline conditions, erosion rates, and provided recommendations for enhancing the coastal resource.

Shoreline Enhancement Study for the City of Hampton (Espey, Huston and Assoc., Inc and Langley and McDonald, 1988)

This report provided a thorough description of the coastal processes that affect he Hampton shoreline and discussed the condition of the beaches, as well as the state of the existing shoreline protection structures. In addition, recommendations were made for future shoreline enhancement, sand sources and funding mechanisms.

Section 933 Evaluation Reports for Grandview Beach, Salt Ponds Beach, White Marsh Beach, and Buckroe Beach (U.S. Army Corps of Engineers, Norfolk District, 1989)

These studies evaluated the potential for placing sandy material dredged from Norfolk Harbor on to the Hampton shoreline. Due to the expense of pumping sand more than six miles to the various beaches, federal cost sharing was not recommended.

Salt Ponds Inlet Management Plan (Coastal Planning and Engineering, Inc. and URS Consultants, March, 1992)

This management plan discussed the history of Salt Ponds Inlet and the maintenance issues associated with stabilizing the inlet. A sediment budget was developed and recommendations were made for structural improvements to the jetties, as well as continued maintenance dredging.

Chesapeake Bay Shoreline, Hampton, Virginia – Hurricane and Storm Damage Protection Study (Norfolk District – U.S. Army Corps of Engineers, March, 1995)

This report detailed the reconnaissance phase of a Hurricane and Storm Damage Protection Study along the shoreline to determine eligibility for a federal storm protection project. The results of the study indicated that there was a positive storm protection benefit relative to projected costs in continued beach renourishment along the public beach at Buckroe. The City of Hampton agreed to participate in the feasibility portion of the study.

Hampton Beachfront Storm Protection and Management Plan – Phase I (Waterway Surveys & Engineering, Ltd., Virginia Institute of Marine Science, and URS Greiner Woodward Clyde, Draft - July 1999)

The report was the first phase of a management study conducted along the Hampton shoreline. Components included a baseline topographic and hydrographic survey, historical shoreline analysis, hydrodynamic modeling to evaluate wave conditions, currents, patterns of sediment transport, and storm erosion modeling. Based on the Phase I results, recommendations were made for various management practices to be considered and modeled in Phase II of the planning process.

Hampton Beachfront Storm Protection and Management Plan (URS Greiner Woodward Clyde, Waterway Surveys & Engineering, Ltd. and Virginia Institute of Marine Science, Draft – March 2002)

This report included empirical and numerical modeling to determine the applicability and potential success of various shoreline management strategies along the shoreline. The strategies evaluated included repairs to the existing groins, construction of strategically placed breakwaters and additional renourishment along the majority of the Hampton shoreline. Cost estimates and preliminary designs were provided for the recommended set of management strategies. The plan also included two years of participation from citizens living in Grandview and Buckroe to help establish community goals and priorities. An update of this report and the Phase I report are the basis of this current plan.

Floodplain Management Plan for the City of Hampton (Gannett Fleming, March, 2002)

As part of the federal Shoreline Protection Study, the Corps of Engineers required that the City develop a Foodplain Management Plan. Some of the plan recommendations included continued stormwater improvements, regulation of new development through the Site Plan Ordinance, preservation of environmentally sensitive areas, as well as various educational initiatives through Public Works.

Final Detail Project Report and Environmental Assessment – Chesapeake Bay Shoreline, Hampton, Virginia – Hurricane and Storm Damage Reduction Study (Norfolk District, U.S. Army Corps of Engineers, April 2002)

The Corps of Engineers' feasibility study for the Hampton shoreline was authorized by Section 114 of the Water Resources and Development Act (WRDA) of 1992 and initiated in April, 1999. The objectives of the study were to evaluate the Federal interest, costs, benefits, environmental impacts, and commitment of the City of Hampton in developing an optimal solution for storm protection. Tasks completed as part of the study included a sand source investigation, a detailed environmental assessment, engineering and planning documentation, a federal economic and alternatives analysis, and a proposed federally preferred plan. The recommendations were that the public beach at Buckroe qualified for a federal project. The City also chose to include renourishment along the public beach at Salt Ponds as a "betterment" to the federal project. This report finalized the details of the project design and environmental assessment.

Shoreline Evolution, City of Hampton, Virginia, Chesapeake Bay and Back River Shorelines (VIMS, Shoreline Studies Program, 2005)

This report discusses shoreline evolution along the City of Hampton. Four reaches were analyzed including the Hampton/Newport News City line to Mill Creek, Old Point Comfort/Fort Monroe north to Salt Ponds, Salt Ponds to Factory Point, and then the Back River shoreline to Tabbs Creek.

Temporal and spatial relationships of shoreline change and dune characteristics are presented for each of the four segments. In general, historical shoreline change rates from 1937 to 2002 suggest that the Hampton Roads fronting shoreline has eroded at about -0.5 ft/yr, the Fort Monroe shoreline has been somewhat stable, the Buckroe Beach area has been slightly accretional, while the beaches north of Salt Ponds to Factory Point have experienced the most erosion with rates averaging around -4.0 ft/yr.

Fort Monroe Reuse Plan (FMFADA, Adopted August, 2008)

The section on “flood control strategy” discussed preliminary findings on flooding, flood insurance availability and sea level rise throughout the federal property. It also included a discussion on the federally proposed plan for shoreline protection along the Fort’s shoreline and provided recommendations for flood control measures.

Sand Transport and Shoreline Evolution Modeling at Factory Point to Evaluate Breakwater Design Alternatives (URS Corporation, July, 2008)

Sediment transport modeling was conducted along the north end of the Grandview Nature Preserve in order to support the design of the breach restoration at Factory Point and to provide additional information for management planning. GENESIS was used to model existing shoreline conditions and then to evaluate various proposed breakwater configurations in the vicinity of the breach. The analysis indicated that the shoreline protection from the breakwaters is more sensitive to the breakwater thickness and height, than to the breakwater length.

Resource Management Plan for Grandview Nature Preserve, City of Hampton, Virginia (Virginia Department of Conservation and Recreation, NOAA, and City of Hampton, September, 1999 – Updated May, 2009)

The management plan for the Grandview Nature Preserve was developed to support preservation and enhancement of the existing natural heritage resources. The plan provides information on the site and its surroundings, a description of the resources and guidelines for conservation planning.

Salt Ponds Inlet Management Plan – Executive Summary (Kimley Horn and Associates, January, 2010)

Although inlet improvements were completed in 2005, the channel has continued to rapidly shoal causing hazardous navigation conditions. The updated management plan was commissioned to develop concepts for inlet improvements to reduce the rate of shoaling and the frequency of dredging. Hydrodynamic modeling and a shoaling analysis, were conducted to evaluate potential engineering solutions. The plan concluded that the existing structures were not effective in maintaining the inlet. Preliminary recommendations included raising and lengthening the south jetty with rock, extending the north jetty, and construction of a 300 ft breakwater near the mouth of the inlet.

1.5 Report Conventions

In order to discuss shoreline management alternatives, the Hampton shoreline has been divided into eight different reaches. These reaches reflect physiographic, as well as land use and ownership boundaries along the shoreline. Figure 1-2 depicts the locations of the eight beachfront reaches, while Table 1-1 provides a description of the physical boundaries for each reach. Physiography, modeling results, and shoreline improvements are provided relative to these defined reaches. Note that the entire bayfronting shoreline of Fort Monroe has been included as part of this study area. Fort Monroe, however, has produced its own management plan and the components are provided in (FMFADA, 2008). The recommendations from that plan will be included in this report but information provided for Reach 1, will focus on Dog Beach in Fort Monroe and Thimble Shoals Court.

Due to its lengthy record and its proximity to the Hampton shoreline, the Sewells Point tide gage is used as the reference gage for reporting in this plan. Comparison of recent tide data collected in Back River show that the high water levels inside Back River (near the mouth) are about 0.3 ft lower than what is recorded at Sewells Point. The phasing and the amplitude of the tide records are very similar. Tide data provided in this report have been updated to reflect the 1983-2001 tidal epoch, when possible. Due to sea level rise/ subsidence issues, there was a correction at the Sewells Point tide gage of about .34 to .38 ft. Therefore, tide elevations presented in this report may appear different than what has been previously cited in other reports.

Finally, site conditions, wind and tide data, shoreline change rates and management alternatives have been updated in this report. RCPWave, EDUNE and GENESIS model results were conducted by Waterway Surveys and the Virginia Institute of Marine Science, Shoreline Studies Program in 1997 and 1998 as part of the Phase I – Hampton Management Plan. These results are still valid and have not been updated for this plan. Tide levels reported in those model runs have not been updated and are still relative to the old tidal epoch.

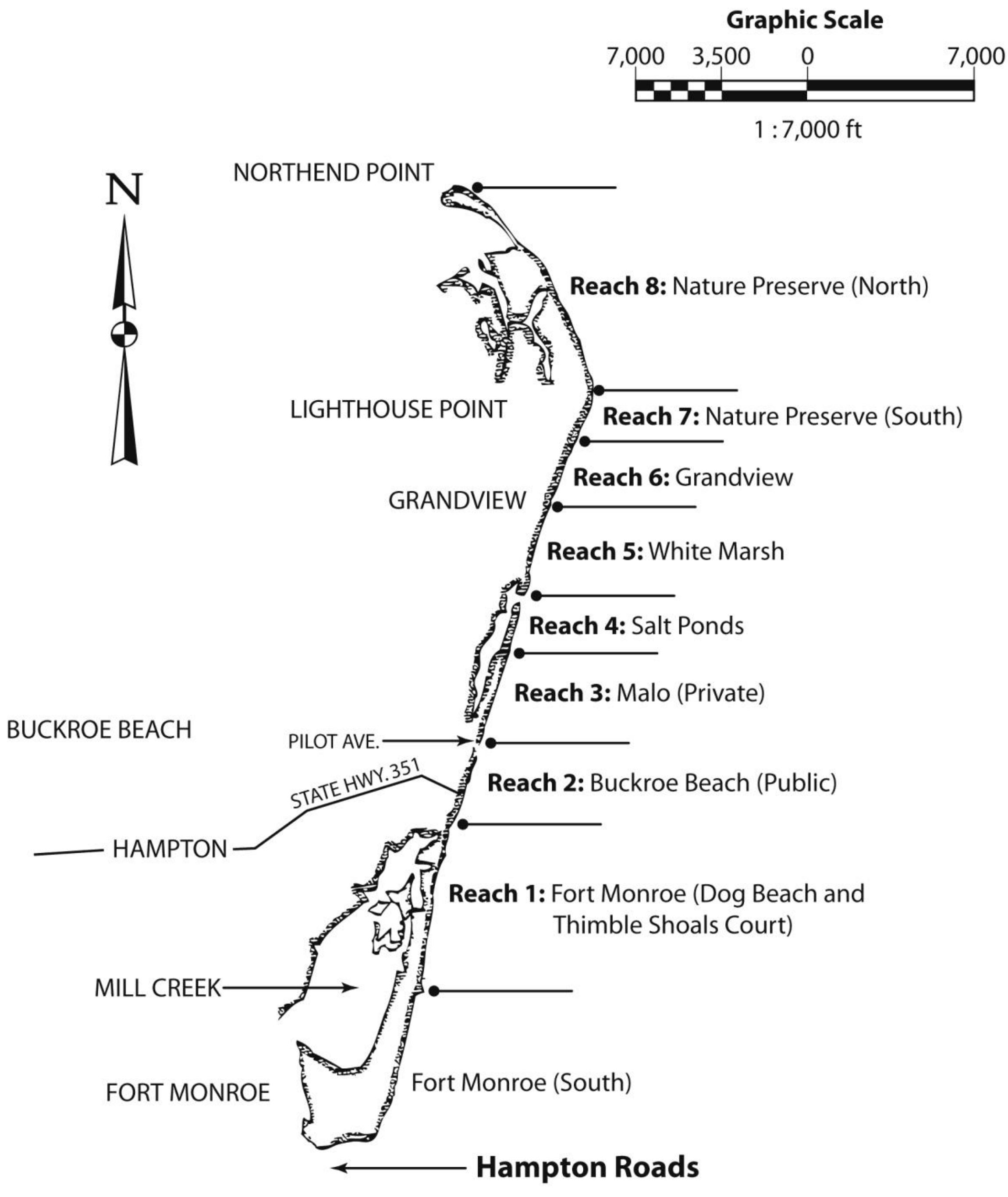


Figure 1-2 Shoreline Reaches

Figure 1-2: Location of Shoreline Reaches Along Hampton.

Table 1-1: Description of Shoreline Reaches.

Reach	Boundary Description
Southern Fort Monroe	Southernmost section of Fort Monroe (8,950 ft) Seawall section of Fort Monroe
1	Fort Monroe (Dog Beach) and Thimble Shoals Court (4,320 ft) Seawall at Fort Monroe north to the Buckroe Fishing Pier
2	Buckroe Beach - Public (4,020 ft) Buckroe Fishing Pier north to Pilot Avenue
3 (A & B)	Malo Beach - Private (3,890 ft) 3A - Pilot Avenue north to the curve in First Street where there is a well developed beach and dune system (1,300 ft) 3B - The curve in First Street north to the end of First Street, this section lacks a dune system and has a very narrow berm (2,590 ft)
4	Salt Ponds Public Beach (2,050 ft) End of North First Street north to the Salt Ponds Inlet
5	White Marsh (3,965 ft) Salt Ponds Inlet north to the Grandview Fishing Pier
6	Grandview (2,900 ft) Grandview Fishing Pier north to Hawkins Pond
7	Grandview Nature Preserve - South (2,450 ft) Hawkins Pond north to Lighthouse Point
8	Grandview Nature Preserve - North (11,000 ft) Lighthouse Point north to Northend Point

2.0 PHYSICAL COASTAL PROCESSES

The following narrative describes the baseline physical conditions along the Hampton shoreline. A summary of coastal processes, wave modeling and storm tides has been included to provide general background information.

The waves that impact the shoreline are directly related to wind events. Wind generates waves through friction and in turn the waves generate currents, which transport sediment. Wind speed, fetch and duration are directly related to wave height. In other words, high winds blowing over a large body of water for a long period of time create large waves. Conversely, light winds blowing across a relatively small body of water for a short time period generate small waves. Wave properties, however, change as they travel toward the shore. Various physical factors affect wave development including bathymetry, the roughness of the seabed, sediment type, and the direction of wave movement. Wind patterns, fetch (open water) windows relative to the shoreline, the changing depths of the offshore region (shape) and the shoreline orientation are all important physical factors that affect coastal processes.

2.1 Wind

Figure 1-1 shows that the majority of the Hampton shoreline (Reaches 1 through 7) is oriented from the north-northeast (Lighthouse Point) to the south-southwest (Fort Monroe). Reach 8 extends from Factory or Northend Point to Lighthouse Point and is oriented in a northwest to southeast direction. As a result, the two greatest fetch windows that impact the study area are winds that blow from the east to the southeast from the Atlantic Ocean through the mouth of the Bay and from the north to northeast down the main axis of the Chesapeake Bay.

Norfolk Airport wind data from 1945-2010 were analyzed to determine the long-term wind frequencies relevant to the area. These data suggest that the northerly component or wind blowing from the north is the dominant wind direction. Winds from the southwest are the second most frequent direction, followed by the winds from the south and northeast. The strongest winds, those with speeds ranging between 30 and 40 mph occur approximately 0.2 percent of the time and are most frequently from the northeast. These strong winds blow down the Chesapeake Bay and generate the high tide and wave conditions associated with the “northeaster” storms. Due to the orientation of the study area, these storm conditions have a significant impact on the Hampton shoreline. Data from the Norfolk Airport suggest that winds blowing from the southeast direction or in from the Atlantic Ocean are associated with the greatest fetch, but are the most infrequent winds.

2.2 Waves

During the late 1980's through mid 1990's, a directional wave gage was located in Hampton Roads. The data collected from the directional wave gage is directly related to the Hampton shoreline. This type of gage was very useful because it measured the height and period, as well as the direction of wave propagation. A review of the data collected at different time intervals from 1988 to 1993, revealed that there was a bimodal distribution of wave directions, which indicated that there are two separate energy sources or types of waves that impact the Hampton shoreline. In simplified terms, there are waves that are generated within the Chesapeake Bay, and those waves that are generated from the Atlantic Ocean and propagate towards shore through the mouth of the Bay (bay-external waves). Data from the wave gage show that 75% of the waves impacting the Hampton shoreline are coming from the southeast through the mouth of the bay. The other 25% are considered bay-internal waves, some of which are created during northeast and northwest storms (Boon, et al, 1992 and 1994).

Almost all of the fall and winter waves with heights greater than 2 feet were directed south, thus generated within the Bay. These fall and winter waves result from northeasters (extra tropical storms), which produce strong north winds along the maximum fetch of the Bay (over 100 miles). All of Hampton's shoreline is impacted by these storms, but the northern sections, in particular Reach 8 (Factory Point) are hit the hardest. The passage of these extra tropical, low pressure storms also produces elevated water levels (storm surge), which allow larger waves to propagate farther inland.

A comparison of the wind and wave data correlate very well for the north and northeast wave conditions local to the area (bay-internal conditions.) The wind analysis, however, does not describe swell and shelf originating wind waves that enter the mouth of the Chesapeake Bay. This is probably due to the fact that these waves are generated out in the ocean by meteorological conditions not represented by the local wind field.

2.3 Wave Climate Modeling (RCPWAVE)

The direct analysis of wave data can be a difficult and cumbersome task. Numerical modeling allows generalizations to be made from a large amount of data. This is important because wave parameters in one area do not necessarily reflect the wave parameters in another region close by. This is particularly true in the Chesapeake Bay where there are complex bathymetric features that significantly alter waves as they travel toward the shore.

RCPWAVE, a numerical computer model developed by the U.S. Army Corps of Engineers (Ebersole *et al.*, 1986) was used to determine changes in waves as they progress toward the Hampton shoreline. This model quantifies changes in wave height, direction, and energy along the shoreline due to the affects of refraction, diffraction, shoaling, and frictional dissipation. The model has been modified by oceanographers at VIMS who have added routines, which employ wave bottom boundary layer theory to estimate wave energy dissipation due to bottom friction (Wright *et al.*, 1987). RCPWAVE assumes that only the offshore bathymetry affects wave transformation; the application does not include the effects of tidal currents.

Example output plots of the wave trajectories for the two most common wave conditions are shown in Figures 2-1(A-D). These two particular wave conditions represent 26 percent and 12 percent of the actual wave data recorded at the directional wave gage in Hampton Roads. Both conditions are associated with incident waves that are 0.4 meters high (1.3 ft) and have a 6.5 second period. The only difference between the two waves is the direction of propagation. Figures 2-1A and 2-1C represent the most common wave, which has an incident angle of 280°E TN or from the northwest, while Figures 2-1B and 2-1D are associated with an incident angle of 300°E TN (north northwest).

One important management result of the RCPWAVE analysis is that it can help identify "hot spots" of erosion along the shore by identifying areas of wave convergence (concentration of several wave rays) or stable areas in areas of divergence (where the wave rays spread out.) Figure 2-1A (280° E TN) shows two convergent zones along the public beach at Buckroe (noted by the darker lines or higher density of wave rays), and Figure 2-1B (300° E TN) shows a convergence between Reach 3A and 3B. Figure 2-1C (280° E TN) shows a very slight convergence in Reach 5 (White Marsh) and Reach 7 (Nature Preserve). Similarly, Figure 2-1D (300°E TN) shows a stronger convergence in Reach 5, but the zone in Reach 7 has shifted to the northern section of Reach 6 in Grandview. These are only two individual cases run through RCPWAVE, but show the effects of wave direction and bathymetry on wave energy. In these cases, it appears that the waves which are generated closer to true north better identify the "hotspot" areas of erosion documented through photographs and beach profiles.

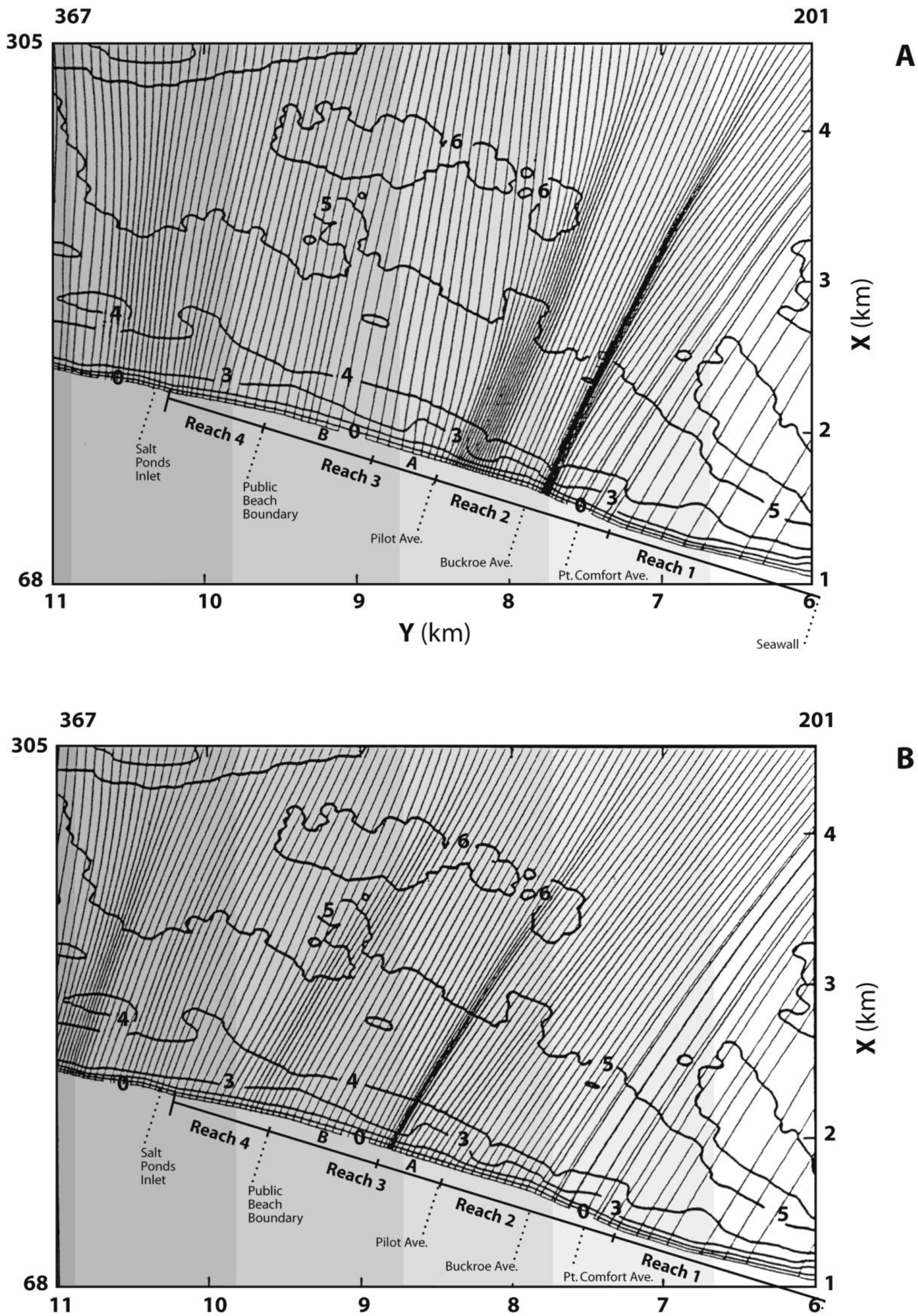
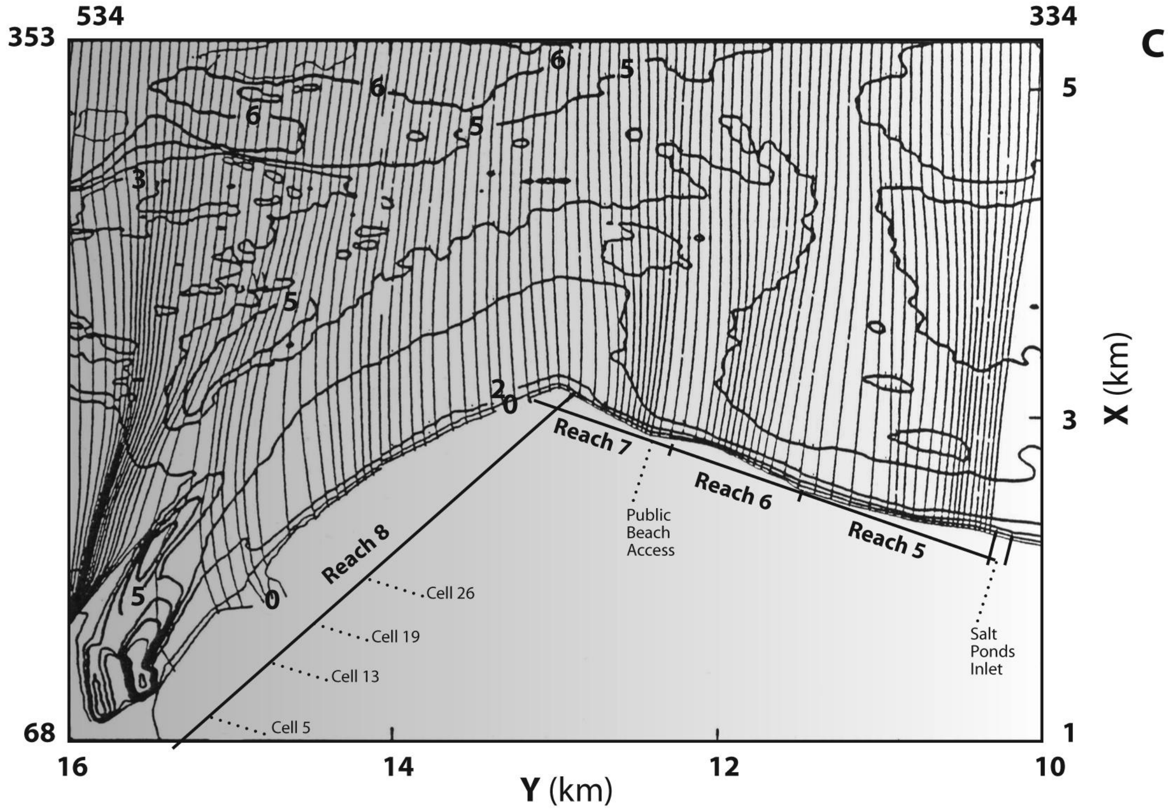


Figure 2-1(A-B): Zones of convergence and divergence in Reaches 1 – 4 resulting from a 1.3 ft incident wave with a 6.5 sec period. (A) Wave angle = 280º TN (B) Wave angle = 300º TN



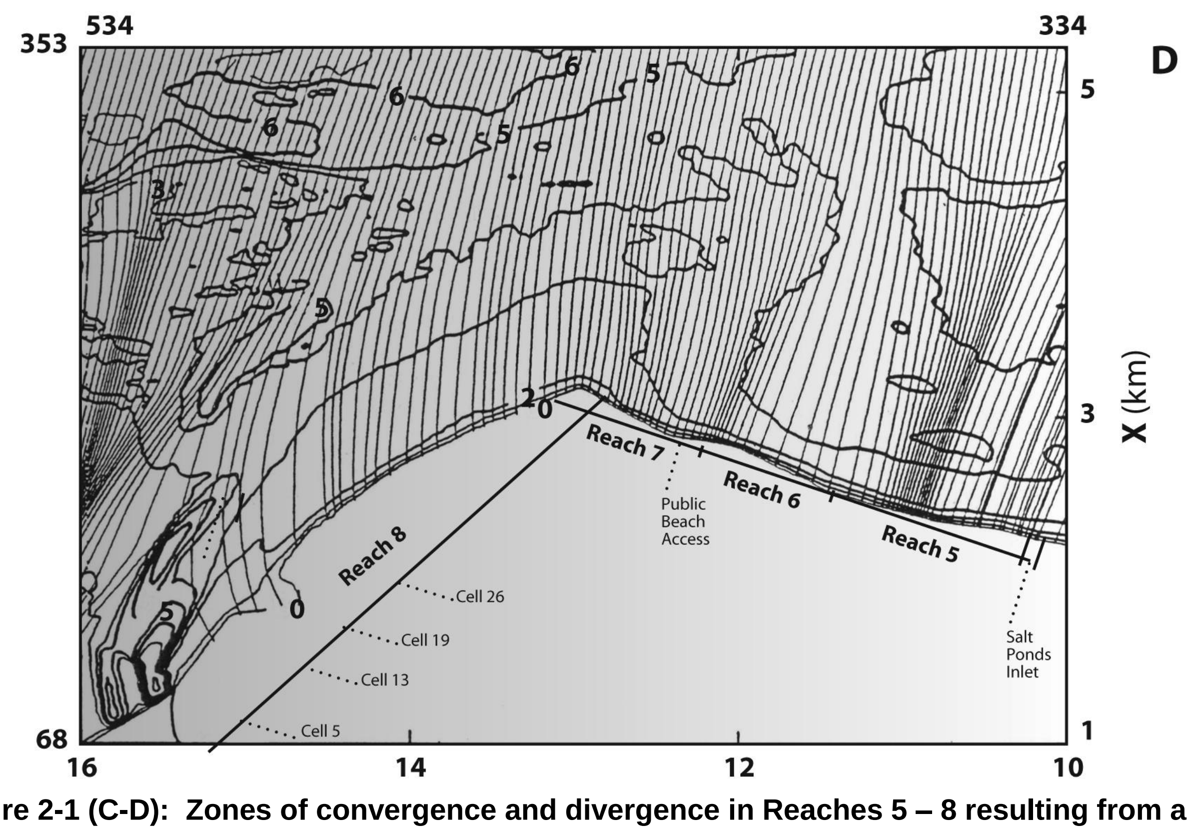


Figure 2-1 (C-D): Zones of convergence and divergence in Reaches 5 – 8 resulting from a 1.3 ft incident wave with a 6.5 sec period. (C) Wave angle = 280º TN (D) Wave angle = 300º TN.

2.4 Tides

Astronomical tides in the Chesapeake Bay are semi-diurnal meaning that there are approximately two high and two low water elevations each day. The mean tide range is the difference between the average high and low tides over a 19-year tidal epoch. At the Sewells Point gage in Hampton Roads, the mean tide range is about 2.43 ft and the ebb and flood current velocities average about 2.5 ft per second. Table 2-1 provides the relationships of the various tidal datums at the Sewells Point gage during the 1983 to 2001 tidal epoch.

Table 2-1: Elevations of tide (ft) relative to various datums at Sewells Point for the 1983 to 2001 tidal epoch.

Tidal Datum (1983-2001)	Elevation, ft MLLW	Elevation, ft MLW	Elevation, ft NAVD
Mean Lower Low Water (MLLW)	0.00	-0.13	-1.65
Mean Low Water (MLW)	+0.13	0.00	-1.52
North American Vertical Datum 1988 (NAVD)	+1.65	+1.52	0.0
Mean Seal Level (MSL)	+1.35	+1.22	-0.30
Mean High Water (MHW)	+2.56	+2.43	+0.91
Mean Higher High Water (MHHW)	+2.76	+2.63	+1.11
Highest Tide on Record	+8.02	+7.89	+6.38

2.5 Coastal Storms

The severity of coastal storms is often based on the elevation of the storm tide. High water elevations not only cause flooding, but also allow wave energy to propagate further inland. A review of nearly eighty years of data from the Sewells Point gage showed that a tide elevation of 3.64 ft MLLW (1.99 ft NAVD) is typically exceeded each month, while each year the highest annual tide elevation exceeds about 5.05 ft MLLW (3.40 ft NAVD). (Mean high water averages 2.56 ft MLLW.) Therefore, at least once each year, the Hampton shoreline experiences tide heights about twice their normal elevation.

Table 2-2 provides the rank and return interval of the highest recorded tide levels at Sewells Point from the time period 1930 to 2010. National Ocean Survey (NOS) historical tide data show that since 1930, still water tide levels at Sewell's Point have exceeded an elevation of 6.0 ft MLLW (4.35 ft NAVD) at least thirteen times. (Five of those storms have occurred within the past decade). The majority of the highest tides are associated with extra tropical storms or northeasters. These low pressure systems do not typically generate wind speeds as high as a tropical storm or hurricane, however, their duration is often much longer. As a result, a northeaster often impacts the coast for several hours (to several days), which can elevate the water elevation for several phases of the tide.

In general, the low lying structures throughout the City of Hampton tend to experience flood damages when the still water level at Sewells Point reaches about 6.25 ft MLLW (4.6 ft NAVD). Still water levels have exceeded that elevation ten times during the past 80 years – twice during the 1930's, once each decade during the 1950's, the 60's, the 70's, and the 90's and four times during the past ten years. The 4.6 ft NAVD elevation was not exceeded during the decades of the 1940's or the 1980's. The still water levels at Sewells Point suggest that during the past decade there has been a significant increase in storm tides high enough to cause flooding.

Table 2-2: Rank and Return Interval of the Twenty Highest Tides Recorded at Sewells Point in Hampton Roads from 1930 to 2010.

Rank	Year	Month	Highest (ft, MLLW)	Highest (ft, NAVD)	(Tr, yrs) Weibull
1	1933	8	8.02	6.38	82.0
2	2003	9	7.89	6.24	41.0
3	2009	11	7.73	6.08	27.3
4	1962	3	7.22	5.58	20.5
5	1936	9	6.72	5.07	16.4
6	2006	11	6.63	4.98	13.7
7	1998	2	6.58	4.93	11.7
8	2006	10	6.52	4.87	10.3
9	1978	4	6.41	4.76	9.1
10	1956	4	6.32	4.67	8.2
11	2009	12	6.15	4.51	7.5
12	1933	9	6.12	4.47	6.8
13	1998	1	6.04	4.39	6.3
14	1999	9	5.97	4.33	5.9
15	1956	9	5.92	4.27	5.5
16	1960	9	5.92	4.27	5.1
17	1982	10	5.9	4.25	4.8
18	2008	9	5.86	4.22	4.6
19	2010	2	5.76	4.12	4.3
20	1957	10	5.62	3.97	4.1

3.0 PHYSIOGRAPHY

Section 2 described tides, wind and wave characteristics and how differences in offshore bathymetry, shoreline orientation and wave angle change the energy patterns. Section 3 concentrates more on the physiography of the beach or the physical shape and how the varying hydrodynamic forces change the beach shape or planform. Physiography is often discussed in terms of shoreline movement (or patterns of erosion and accretion.) Figure 3-1 provides an illustration of the various beach plan form features presented throughout this section.

Predictive models of shoreline movement and dune erosion have also been used to numerically describe the long and short-term changes in the physiography along each of the reaches. Once the dynamics between the physical forces and the physiography are better understood and can be accurately modeled, then they can be used to predict change. These computer models are particularly useful for evaluating alternatives for shoreline protection and beach renourishment design.

3.1 Mechanisms of Sediment Transport

There are four basic mechanisms of sediment transport in the coastal zone including aeolian transport (wind blown sediment), longshore or littoral transport (sediment moving parallel to the shoreline), cross-shore transport (sediment moving perpendicular to the shoreline or in an onshore/offshore direction) and overwash (sediment moving over top of the berm and dune system). Aeolian transport is an important mechanism because it assists in the creation of dunes and is responsible for redistributing sediment along the upper portion of the beach berm. Overwash processes are typically associated with storms. This is also an important mechanism of sediment transport because sediment that is moved inland past the primary dune is often lost to the nearshore system and is considered a sediment “sink”.

The littoral and cross-shore transport components are the predominant mechanisms of sediment movement throughout the nearshore zone. These two mechanisms of transport are directly related to the interactions between wave climate and the bathymetry (as introduced in Section 2). Larger waves (in terms of height and length) approaching the shoreline at a greater angle potentially generate stronger longshore currents. Those waves that approach the shore in a normal direction potentially move the sediment onshore or offshore. The steeper or storm waves (greater height to length ratio) move sediment offshore, while flatter or swell waves tend to move sediment onshore.

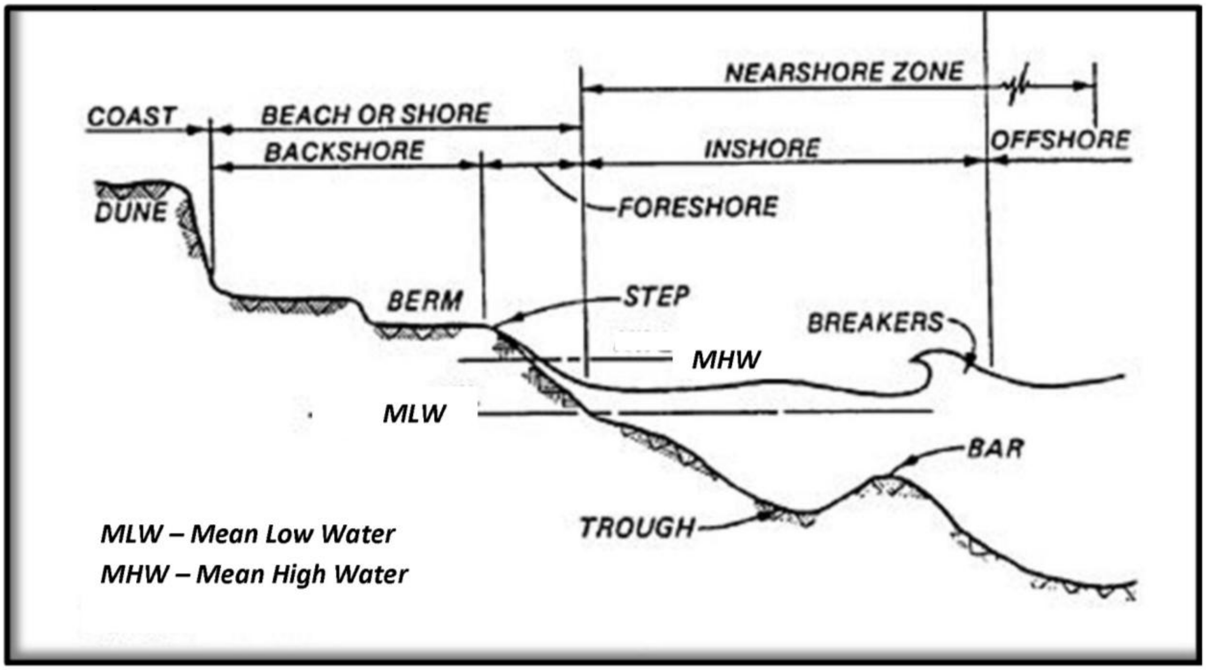


Figure 3-1: Depiction of beach physiography with descriptive terms (modified from Krause and Larsen, 1988).

3.2 Patterns of Shoreline Movement

This section describes historical and recent patterns of shoreline movement along Hampton's beaches. Figures 3-2 (A-C) depict the historical changes in the shoreline along Hampton, as well as estimated rates of erosion or accretion. Aerial photography, maps and charts from 1937, 1963, 1987 and 1997 were used to develop Figures 3-2 (A-C). There are, however, some limitations on the interpretation and analysis of historical maps and charts as they are not as accurate as the comparison of physical survey data. The historical data, however, provide relevant information on general trends of shoreline movement and development.

Since 1990, beach profiles have been measured on an annual basis at specific range monuments from Fort Monroe (Section 1) through the southern end of the private portion of Buckroe Beach (Section 3A). A comparison of the beach profile data provides important information on the performance of the beach renourishment projects, as well as background shoreline change rates. Figures 3-3 and 3-4 represent contour change rates (ft/yr) for both the project equilibration, and the general trend or "background" rate of shoreline movement, respectively.

3.2.1 Reach 1 (Fort Monroe and Thimble Shoals Court)

3.2.1.1 Historical Trend (Charts and Aerial Photography)

From 1937 to 1987, Fort Monroe experienced modest erosion and recession rates averaged -2.0 ft/yr. Once the renourishment project was constructed at Buckroe, it served as a feeder beach and supplied sand to the southern beaches. As a result, the shoreline accreted an average of almost 10.0 ft/yr between 1987 and 1997. Since that time the shoreline has been receding. VIMS (2005) suggests that the Fort Monroe shoreline has been eroding at an average rate of about -0.4 ft/yr between 1994 and 2002.

3.2.1.2 Current Trend (Profile Data)

Figure 3-3 shows that immediately after the 1990 renourishment project was constructed, the planform of the beach accreted an average 47.2 ft/yr between 1990 and 1992. Shortly after 1992, once the project equilibrated, the beach began to recede again at an average rate of -3.3 ft/yr (Figure 3-4). Along this reach of shoreline, the estimated historical trend is similar to the calculated background rate from the beach profiles. During the past three years (after the 2005 renourishment project), the MHW line has been receding at a rate of about -17 ft/yr. Figure 2-1A&B, shows that under *normal or typical conditions*, Reach 1 is in a generally divergent area. The historical information, as well as the recent profile data indicate that this reach experiences moderate erosion. *An average erosion rate of -2.0 ft/yr should be used for planning purposes.*

Another interesting observation is noted in Figures 3-3 and 3-4. These figures show that while the overall beach planform was accreting in 1991 and 1992, the lower contours (intertidal and subtidal zones) accreted at a faster rate than the berm or showed more “activity”. This is directly related to the littoral or longshore movement of sand from the renourishment project into this reach. Similarly, when the beach began to erode, the most stable section was the subtidal area. This would suggest that much of the sediment loss from the upper berm resulted from high tide and wave conditions due to coastal storms and not “normal” or typical conditions. The steeper waves tend to transport the sediment offshore where it is more readily available to the longshore transport system.

3.2.2 Reach 2 (Buckroe Beach - Public)

3.2.2.1 Historical Trend (Charts and Aerial Photography)

The shoreline positions from historical aerial photography suggest that the public beach at Buckroe has been stable or accreting since 1937. In this case, *the historical data do not seem to represent our understanding of shoreline conditions throughout this reach*. During the 1960's, however, the bulkhead was constructed at least *50 ft seaward* of the 1937 shoreline position. Once the bulkhead was constructed, the shoreline could not retreat any further, it could only be lowered. Lowering of the beach in front of the bulkhead has been evident, particularly after storms. Several times during the 1970's and 1980's, the bottoms of the concrete steps along the bulkhead were completely exposed, as were the stormwater outfalls. As a result of the siting of the bulkhead and the addition of sand to the system, it is difficult to develop a representative background rate of shoreline change for Reach 2. Historically, however, there has been a need for renourishment at this location, which suggests an eroded condition. Since that time the shoreline has been receding. VIMS (2005) suggests that the Buckroe Beach shoreline has been eroding at an average rate of about -0.4 ft/yr between 1994 and 2002.

3.2.2.2 Current Trend (Profile Data)

Project performance along Buckroe Beach has been monitored since the original project was constructed in 1990. During that time, the rate of volume change has differed both spatially, and through time. The renourishment projects (1990, 1996 and 2005) suffered their greatest losses during the first year. By the end of the second year, the volume change became more steady. The average volume change along the project from 1990 to 1992 was -19.2 cy/ft/yr, while the average change from 1992 to 2004 was -2.0 cy/ft/yr. Plots of shoreline change showed similar results. During the first two years (1990 to 1992) the average change was about –50 ft/yr, while the average change from 1992 to 2001 was –4.9 ft/yr (see Figures 3-3 and 3-4).

Figure 2-1A shows that most of the time, wave energy narrowly converges or is concentrated just south of R-3.2 and is then broadly concentrated just south of Pilot Avenue in the vicinity of R-4 and R-5. As a result, the intertidal and sub-tidal areas of this section would be expected to experience more wave induced sediment movement.. In fact, Figure 3-3 shows that range monuments R-4 and R-5 show the greatest background recession. Data from 2007 to 2010 suggest that the southern end of the renourishment area eroded at a rate of about -17 ft/year (similar to Reach 1), while the northern end (R-3.2 to R-6) eroded at a rate of less than -10 ft/yr. This is opposite of what was found in earlier studies or background studies and is probably due to the positive effects of the breakwater at Buckroe Avenue. (The Point Comfort breakwater had not been constructed at the time of the 2010 survey.)

3.2.3 Reach 3 (Malo Beach - Private)

3.2.3.1 Historical Trend (Charts and Aerial Photography)

Similarly to Reach 2, the historical shoreline positions for the private section of Buckroe Beach depict a stable to accretional system. The 1937 and 1963 photographic representations, however, show that the shoreline was breached or overwashed in at least three locations, depicting a dynamic shoreline vulnerable to storm impacts. A comparison of these two shoreline positions indicates a 2.5 ft/yr rate of accretion in 3A and a -0.5 ft/yr rate of recession in 3B. VIMS (2005) suggests that overall the Malo Beach shoreline has been eroding at an average rate of about -0.4 ft/yr between 1994 and 2002.

With the exception of the large continuous bulkhead, the development history of Reach 3 is similar to Reach 2. After the Ash Wednesday storm, numerous individual seawalls and bulkheads were constructed to protect homes from storms. These structures, particularly in Reach 3B, have somewhat anchored the shoreline position, but have also assisted in lowering the beach planform. Although the historical shoreline conditions do not show particularly eroded conditions, due to the narrow width and the low elevation of the beach berm fronting the structures, Reach 3B has been particularly susceptible to storm damage. In terms of storm impacts, Reach 3A is not nearly as vulnerable due to the protective dune structure and the offset of the houses and infrastructure from the active beach.

3.2.3.2 Current Trend (Profile Data)

Profile data has been collected annually since 1990 at two monuments located in Reach 3A. Figure 3-3 shows that for two years after the renourishment project was constructed, the beach accreted at an average rate of about 22.7 ft/yr. The highest rate of accretion was in the sub-tidal area, suggesting that this material was transported from the renourishment site through littoral transport. (There are frequent reversals in the littoral transport direction, but net transport is to the south. Thus more sand from the renourishment projects was documented in Reach 1, than Reach 3A.)

Once the 1990 project equilibrated, the area experienced only minor erosion, with rates averaging about -1.0 ft/yr (see Figure 3-4). This rate may be slightly lower due to the fact that the 1996 renourishment project was constructed along the northernmost section of the public beach. Wave modeling results show prevalent reversals in the longshore transport potential at the northern end of the public beach. Therefore, the sand from the 1996 project was more likely to move at a slow rate to the north into Section 3A. This sediment transport trend reverses in Section 3B and as a result, erosion rates would likely be much higher. After reviewing the wave energy results, it is assumed that background erosion rates for 3B would be similar to Reach 1, but less than Reach 2 and would probably average around -2.0 ft/yr. The beach planform along Reach 3B is much lower than the reaches to the north. As a result, this area is highly susceptible to storm impacts.

3.2.4 Reach 4 (Salt Ponds) and Reach 5 (White Marsh)

The historical shoreline change for Salt Ponds and White Marsh is depicted in Figures 3-2A and 3-2B, respectively. These reaches were part of a continuous headland feature in 1937. The headland probably became more prominent as a result of the storms in the 1930's. These two reaches rapidly eroded between 1937 and 1963, which resulted in accretion to the south. Erosion rates were calculated as -7.9 ft/yr and -11.8 ft/yr for Salt Ponds and White Marsh, respectively. Between 1963 and 1987, the rate of erosion significantly decreased at White Marsh, while Salt Ponds started to accrete. This change is attributed to the dredging of Salt Ponds Inlet and the construction of the jetties during the mid to late 1970's. Fill material was placed to the south of the inlet building the beach seaward, while the north jetty started trapping the southerly littoral drift. The 1987 to 1997 historical shoreline change rates show that Salt Ponds had started to erode at a rate of approximately -1.3 ft/yr, while White Marsh accreted at a rate of approximately 1.2 ft/yr. VIMS (2005) suggests that the Salt Ponds and White Marsh shorelines have been eroding at an average rate of -0.6 ft/yr between 1994 to 2002.

Although the White Marsh beaches should benefit from the north jetty at Salt Ponds Inlet, there is very little sediment available to the littoral system since it is trapped between two large man-made structures (the north jetty at Salt Ponds and the revetment at Grandview). As a result, the shoreline immediately north of the inlet should remain stable to slightly erosional, but it will probably not continue to accrete in the future unless sediment is added to the system. It is also important to note that White Marsh is a low lying; thin strip of beach backed by Long Creek and is frequently overtopped during storms. Additionally, some sediment is bypassed from the inlet channel to the south side on to Salt Ponds public beach from maintenance dredging operations. The amount of sediment available for bypassing at this time helps reduce the erosional impacts along Salt Ponds, but is not sufficient to stabilize the southerly beaches.

3.2.5 Reach 6 (Grandview)

The shoreline change history at Grandview (Figure 3-2B) is obscured by the construction of the seawall and revetment during the 1950's, 1960's and 1970's. The shoreline along this reach eroded at an average rate of -3.2 ft/yr between 1937 and 1963. To abate erosion and protect homes, the seawall and various lines of revetment were constructed. These structures anchored the shoreline, but the adjacent areas continued to erode at rates in excess of -2.5 ft/yr. As a result, Grandview currently exists as a headland and the northern section is highly susceptible to north and northeast storm activity. In addition to continued erosion, breaches have occurred subjecting Hawkins Pond to periodic influxes of seawater. VIMS (2005) suggests that the Grandview shoreline has been eroding at a rate of -0.6 ft/yr between 1994 and 2002.

3.2.6 Reach 7 (Grandview Nature Preserve - South)

Grandview Nature Preserve is sited between two fixed points, the hardened shoreline of Grandview and Lighthouse Point. Figure 3-2B shows that the shoreline throughout the Preserve has continued to erode since 1937. The average rate of erosion from 1937 to 1997 has been -5.5 ft/yr. This section of shoreline is exposed to the northern storms and does not benefit from the addition of littoral sediment. There is a reversal in the net littoral direction around Lighthouse Point. Therefore, new sand is rarely supplied naturally to the beaches at the Nature Preserve. The eroded material from Grandview Nature Preserve does tend to migrate to the south, however, since the Grandview seawall serves as a headland, much of this material is diverted offshore. In its current state, the shoreline along the Grandview Nature Preserve will continue to erode. Rates of erosion should diminish, however, since the south side of Lighthouse Point is no longer a prominent headland. VIMS (2005) suggests that the southern end of the Nature Preserve has been eroding at a rate of -0.6 ft/yr between 1994 and 2002.

3.2.7 Reach 8 (Grandview Nature Preserve - Northend Point)

Figure 3-2C shows that the shoreline movement at Northend or Factory Point has been the most dynamic. The southeastern section closest to Lighthouse Point has been relatively stable. The average rate of shoreline change for the first half-mile segment immediately north of Lighthouse Point has been in the range of +0.5 ft/yr since 1937. The spit, however, has historically continued to migrate to the southwest at an average rate of -15 ft/yr. A headland exists between the spit and the segment adjacent to Lighthouse Point. This headland has also historically migrated to the southwest, but the rate has been significantly less than that of the spit. VIMS (2005) estimates that between 1994 and 2002, the northern end of the Grandview Nature Preserve has eroded at an estimated rate of -3.5 ft/yr.

The headland and the spit at Factory Point were extremely low lying with average dune crest elevations less than about 5.5 ft MLLW. As a result, this section of the shoreline was frequently overtopped. In fact, during the fall of 1997 the throat of the spit was completely breached creating an island at Factory Point. The breach widened during the following thirteen years. In 2010, more than 140,000 CY of sand was pumped from the nearshore shoal to reattach the island at Factory Point with the mainland at the Grandview Nature Preserve. In addition, five breakwater structures were constructed to help stabilize the restoration project.

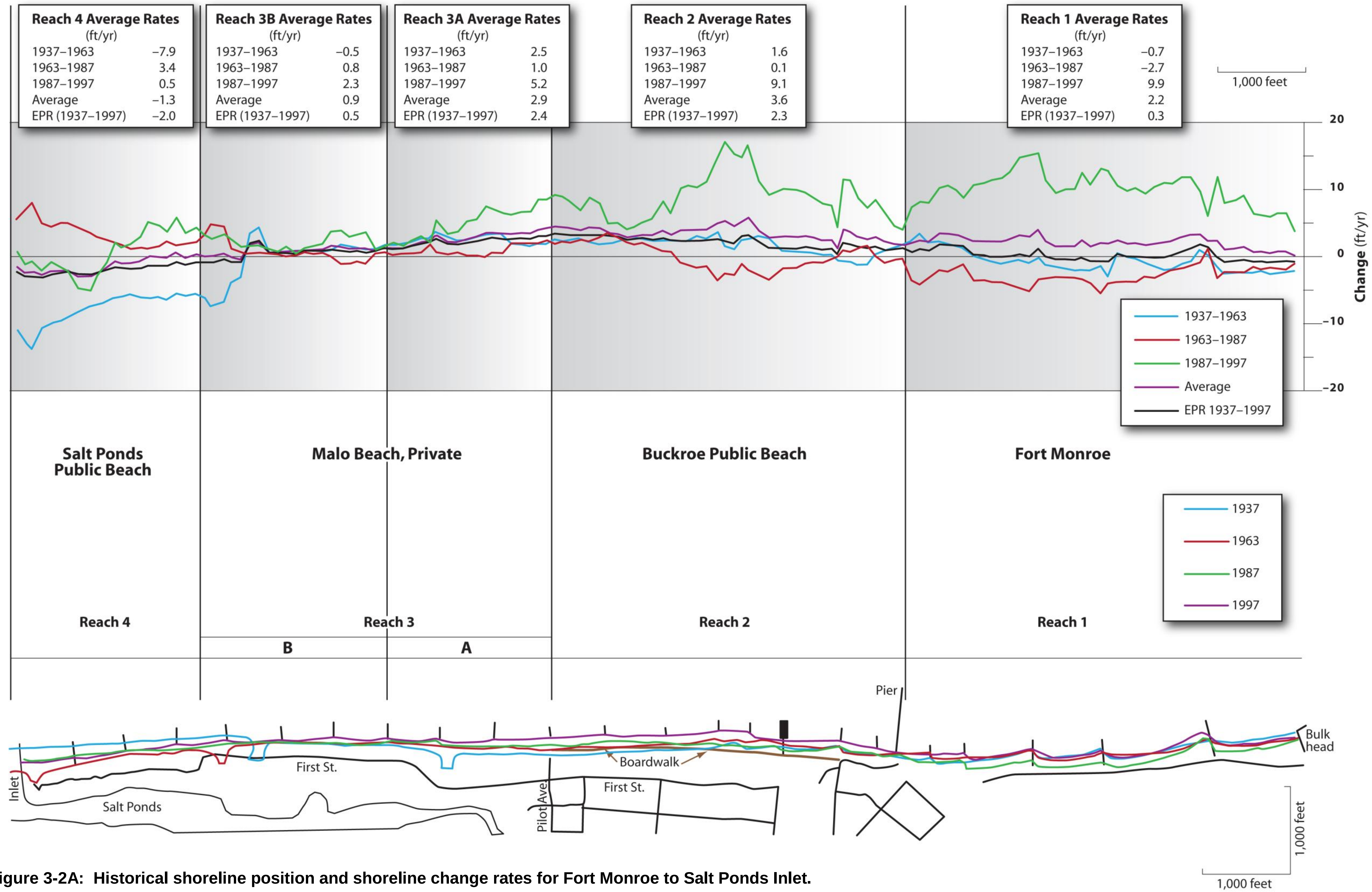


Figure 3-2A: Historical shoreline position and shoreline change rates for Fort Monroe to Salt Ponds Inlet.

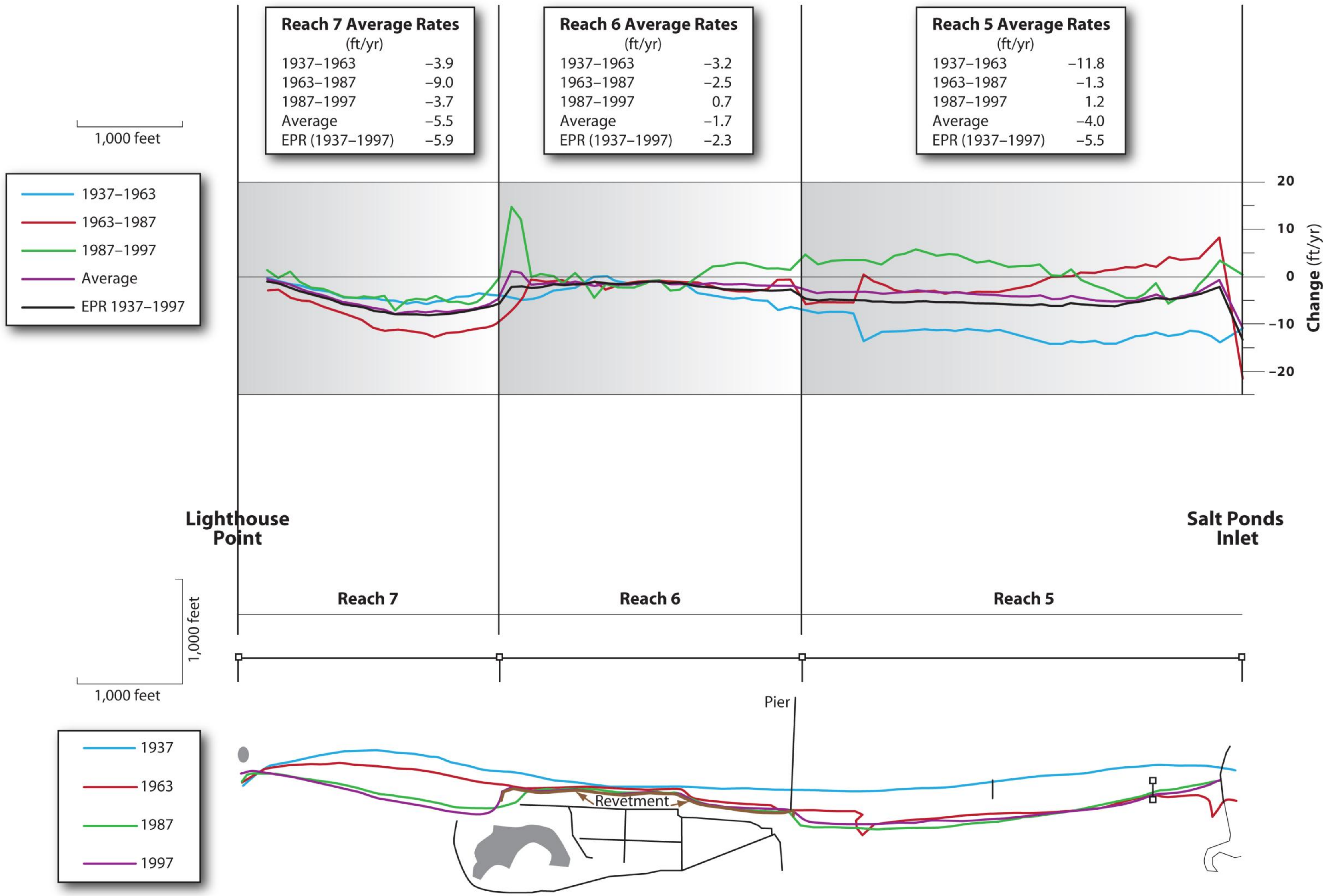


Figure 3-2B: Historical shoreline position and shoreline change rates for Salt Ponds Inlet to Lighthouse Point.

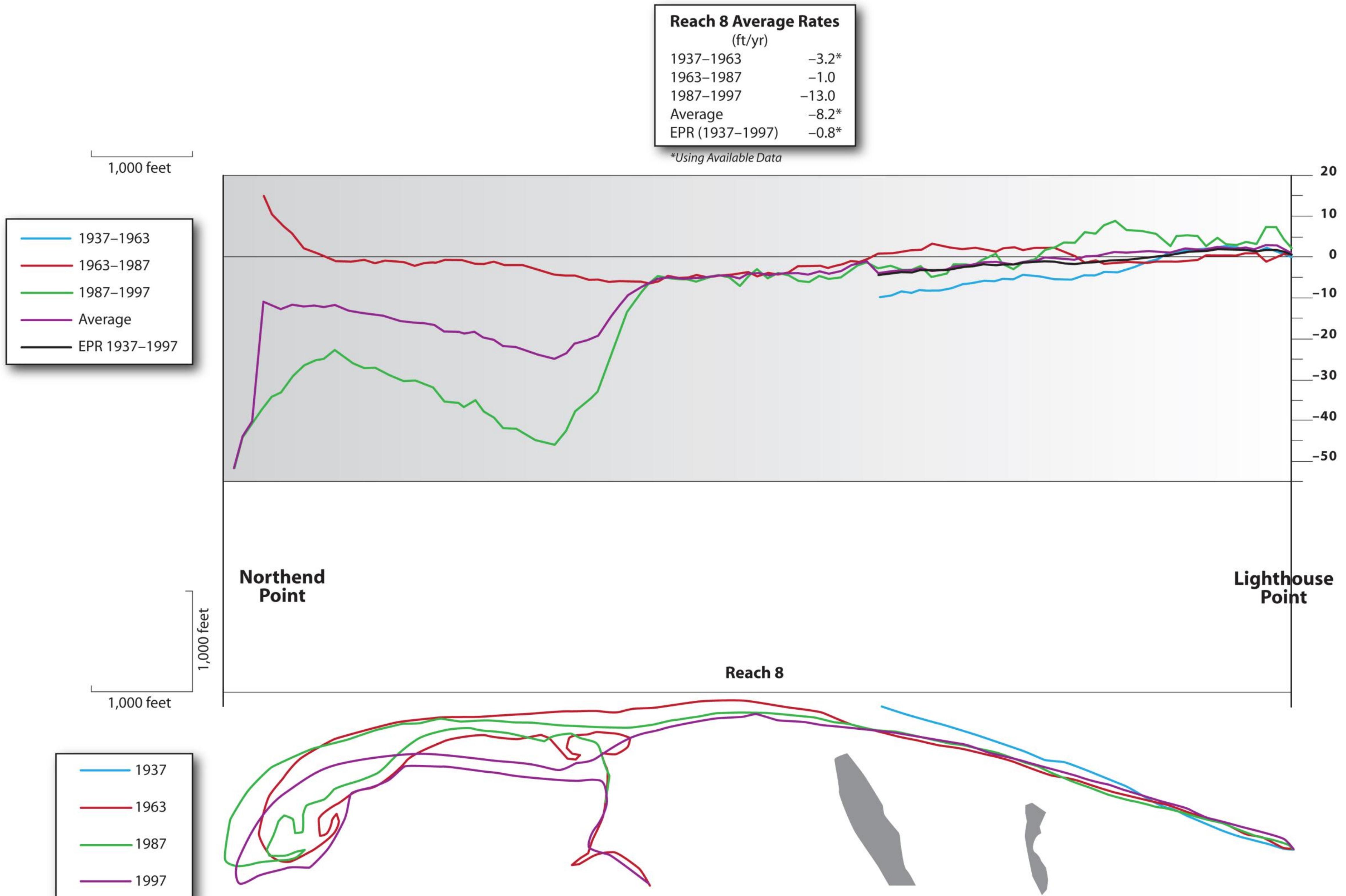


Figure 3-2C: Historical shoreline position and shoreline change rates for Lighthouse Point to Factory Point.

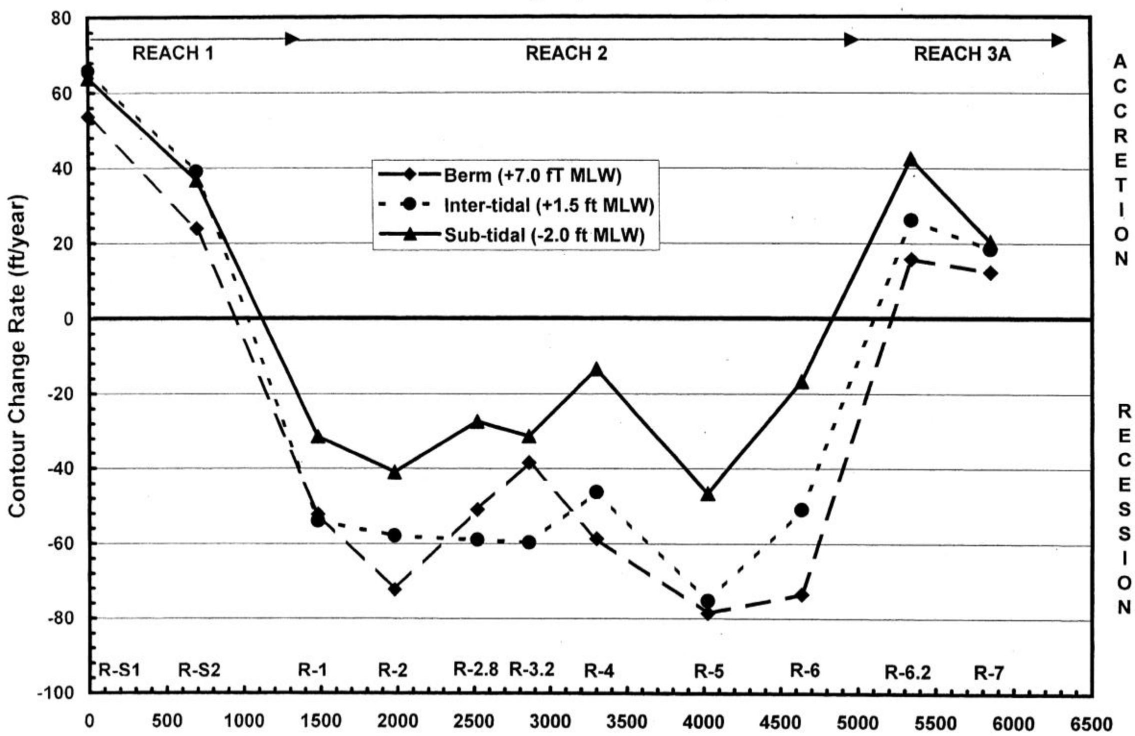


Figure 3-3: Shoreline Change (ft/yr) along Reaches 1-3A from August, 1990 to July, 1992. This rate documents the equilibration of the 1990 renourishment project.

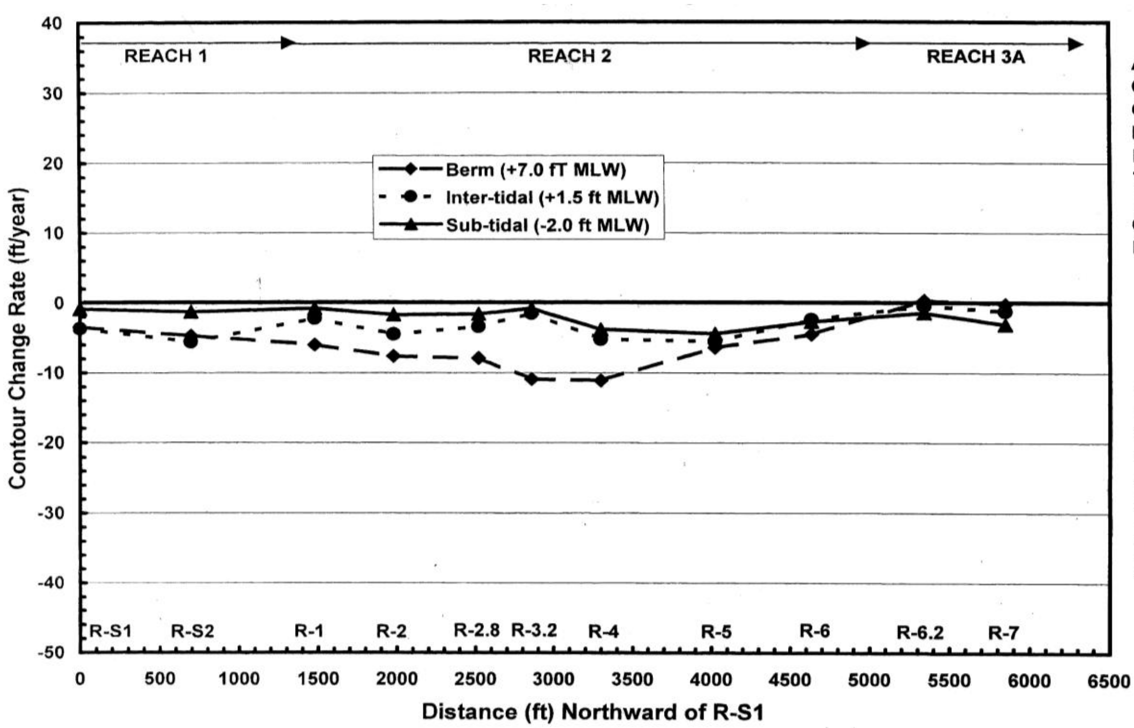


Figure 3-4: Shoreline Change (ft/yr) along Reaches 1-3A from July, 1992 to August, 2001. This rate documents the background shoreline change rate.

3.3 Shoreline Change Modeling (GENESIS)

Numerical shoreline models, such as GENESIS, are often used in management practices to mathematically describe beach conditions. Once historical changes can be assessed with numerical models based on various input conditions, then the models can be used to predict future changes in the beach plan form as conditions are forced to change. Of particular interest is predicting the potential life of beach renourishment projects, storm impacts, as well as changes in the shoreline due to structural improvements.

The GENEralized model for SImulating Shoreline change (GENESIS) was developed by the U. S. Army Corps of Engineers (Hanson, et al. 1989.) It utilizes longshore transport formulae to force shoreline movement based on impinging wave energies (i.e. input from RCPWAVE analysis). In particular, GENESIS describes long-term trends of beach plan shape as the shoreline moves toward equilibrium under specified wave conditions, boundary conditions, configurations of coastal structures and other input parameters.

There are three main components of the GENESIS modeling that will be discussed in this report. First, there is a summary of the model calibration and verification, which determines the usefulness and accuracy of the model in describing known conditions. The second component is the longshore transport potential. This is particularly useful in understanding the longshore changes in sand transport as it moves throughout the littoral system. The third component is provided as Section 6, in which GENESIS was used to model various shoreline improvement alternatives to determine their effectiveness in stabilizing the shoreline.

3.3.1 Model Calibration

Calibration is the procedure of determining values of adjustable coefficients within the model that reproduce a shoreline position measured over a certain time interval (Gravens *et al*., 1991). In the verification procedure, these same coefficients are applied to an independent time period in order to reproduce another measured shoreline. Three separate baselines were developed for the model including Reaches 1 to 4, 5 to 7, and Reach 8. For all three baselines, the depth of closure was used as an adjustable coefficient since onshore-offshore transport in the Bay is not as straight forward as on the ocean coast. Figure 3-5(A-C) shows the location of the 1993 shoreline, the measured shoreline from 1998 and the calculated shoreline.

Some of the problems encountered in calibration and verification were the model's inability to accurately model such closely spaced groins as occur along the Buckroe baseline. In particular, the groins along the Fort Monroe shoreline in Reach 1 (Figure 3-5A) were not modeled accurately. In the verification phase, GENESIS showed accretion along the shore that has not occurred and yet the model under-predicts the amount of sand stacked against the southern-most groin. In Reach 2, the model smoothes out an irregular shoreline, but it also suggests that more erosion is occurring in the northern part of Reach 2 than measured shorelines show. In Reach 3A, GENESIS shows accretion that does not exist in the 1998 shoreline condition. (What is interesting, however, is that although the results do not match the 1998 shoreline condition, they describe the changes in the shoreline that were documented in the year 2001.)

Figure 3-5B shows the calibration results for Reaches 5 through7. GENESIS predicts more erosion at Lighthouse Point than what is actually measured. For the rest of the shoreline, however, there is reasonable agreement between the model's predicted shoreline and the measured January 1998 shoreline. Measured and calculated results for Northend Point (Reach 8) are depicted on Figure 3-5C. Due to the dynamic nature of the spit feature, the model was not able to accurately describe shoreline change.

GENESIS was successful in accurately modeling the shoreline trends along most of the Hampton shoreline and therefore should prove useful in predicting changes due to beach improvements. As previously mentioned, it was difficult to model closely spaced structures, such as the groins in Fort Monroe and along the public section of Buckroe Beach (Reaches 1 and 2). This will continue to be problematic in modeling new structures and beach renourishment in those areas.

3.3.2 Longshore Transport Potential

Figure 3-6(A-C) provides the longshore transport rates for Reaches 1 through 8. It is important to note that the magnitude of the rate, as well as the direction of transport changes along the shoreline. This phenomenon can greatly affect shoreline change rates along the beach. For instance, at points of reversal where the transport diverges or moves in opposite directions, erosion often occurs. Conversely, where there is a convergence in the longshore transport through time, then there is typically accretion or at least beach stability.

Figure 3-6A shows the average longshore transport for the Buckroe Baseline (Reaches 1 to 4). Positive transport is in the southerly direction while negative transport is to the north. For Reaches 1, 2, and 3A the average transport is to the south and the rate of transport increases in that direction. Although the overall transport volume is less, there is an increase in the rate of transport or acceleration throughout Reach 2. At the northern end of Reach 1, the transport rate decelerates and then oscillates around the zero.

The transport shows an overall net loss, resulting in erosion; however the deceleration of the rate suggests there might be a smaller rate of erosion than in Reach 2. This correlates with the measured background rate presented in Section 2.

Figure 3-6A shows that there are two areas of divergence or nodal points where there is a reversal in the average direction of longshore transport. One occurs at the northern end of the public beach (shown as Station 70 on Figure 3-6A) and the other occurs near the middle of Reach 3B (Station 35). The historical and recent survey data show that these two areas of divergence have demonstrated the highest rates of erosion along this baseline (Reaches 1 to 4). Areas of convergence are located in the middle of Reach 3A and Reach 4 (Stations 55 and 10, respectively). Recent survey data shows that Reach 3A is the most stable area along this baseline and has actually showed some signs of accretion. Reach 4 is somewhat stable; however, the zone of convergence may be due more to a modeling boundary condition, than an actual natural phenomenon.

Figure 3-6B provides the longshore transport for Reaches 5 through 7. This diagram shows that the net transport potential from just south of Lighthouse Point through Salt Ponds Inlet is to the south. Southerly transport throughout White Marsh and Grandview is relatively uniform. Reach 7 along the Nature Preserve has the higher transport rate relative to the other two reaches. There is a rapid acceleration in the southerly rate just south of Lighthouse Point, which would suggest potential erosion, while the rate decelerates towards Grandview. This would suggest that accretion should occur on the south side of the seawall. This phenomenon is not observed. The historical data show a highly erosive trend south of Lighthouse Point; however, accretion is not common along the updrift side of the seawall. It is possible that the nearshore zone adjacent to the seawall is relatively deep and steep and the material does not accrete onto the beach through normal littoral processes.

Figure 3-6C provides the longshore transport rate for the shoreline south of Lighthouse Point. The results cannot be specifically verified, however, the trend shows moderate northerly transport from Lighthouse Point toward the spit. This is probably a realistic result. The spit at Northend Point is too dynamic to accurately model.

3.3.3 Summary of GENESIS Results

Based on the results of the calibration and verification procedures, the ability of GENESIS to accurately predict future shoreline change will be limited to regions where it has demonstrated an ability to deal with the complexity of this shore zone. The rates of longshore transport obtained with GENESIS are similar to previously published rates, and the direction of transport is informative relative to identifying patterns of shoreline change. While this model may not accurately predict the shoreline plan forms for each reach, combined with technical expertise in coastal processes it can provide information necessary to the design of a beach protection system.

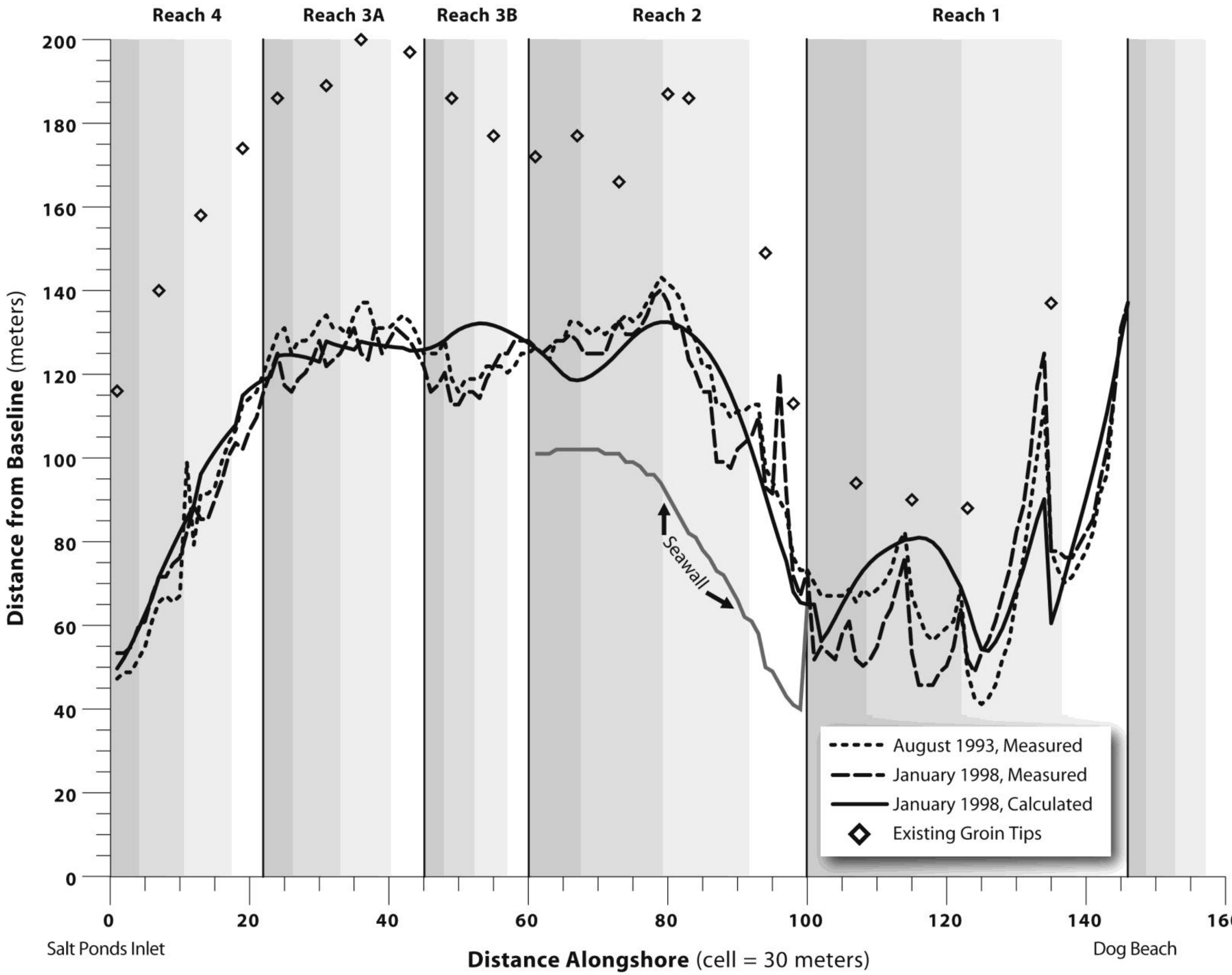


Figure 3-5A: GENESIS model calibration results for Reaches 1 to 4 (Fort Monroe to Salt Ponds Inlet).

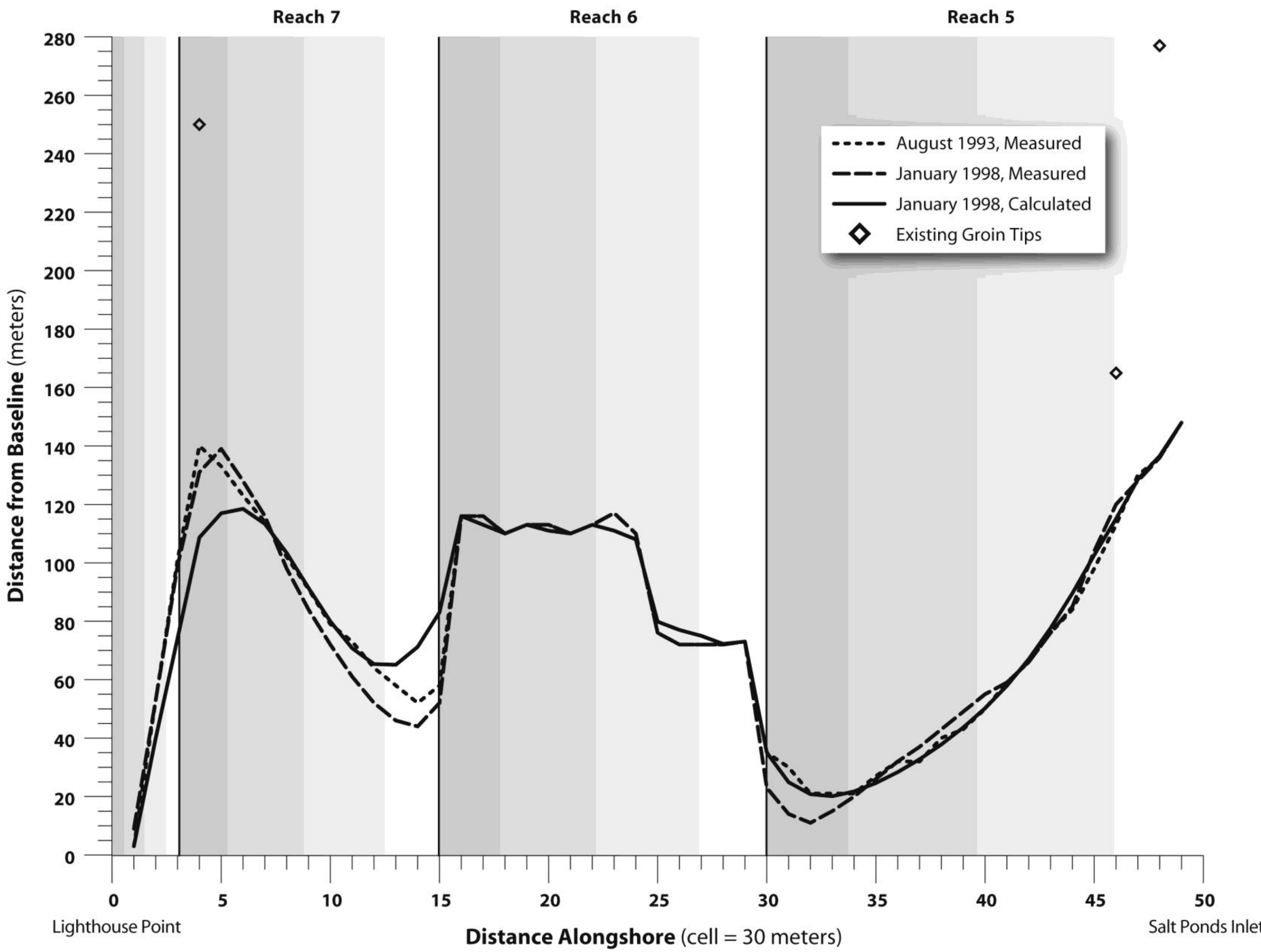


Figure 3-5B: Genesis model calibration results for Reaches 5 to 7 (Salt Ponds Inlet to Lighthouse Point).

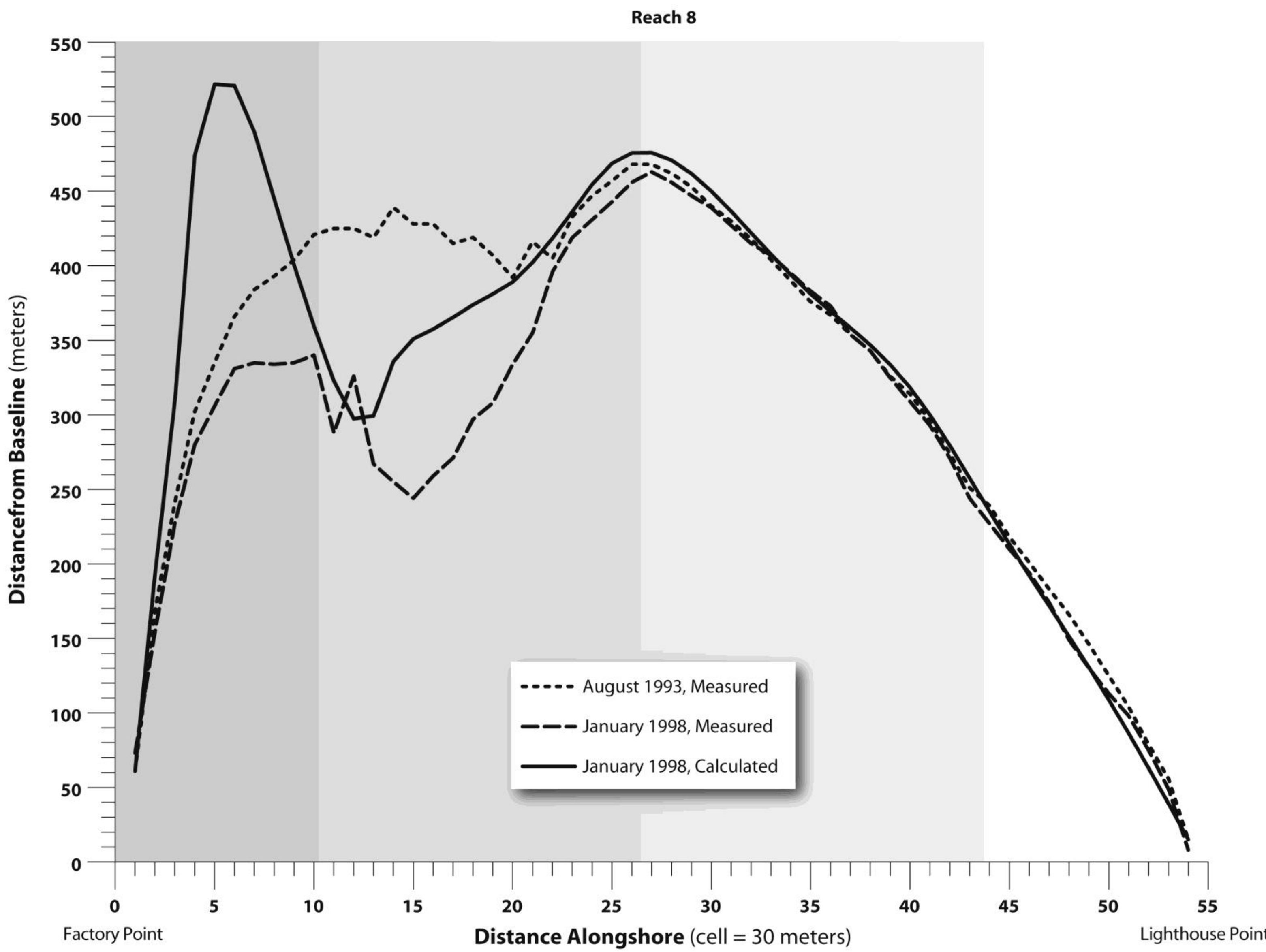


Figure 3-5C: Genesis model calibration results for Reach 8 (Lighthouse Point to Factory Point).

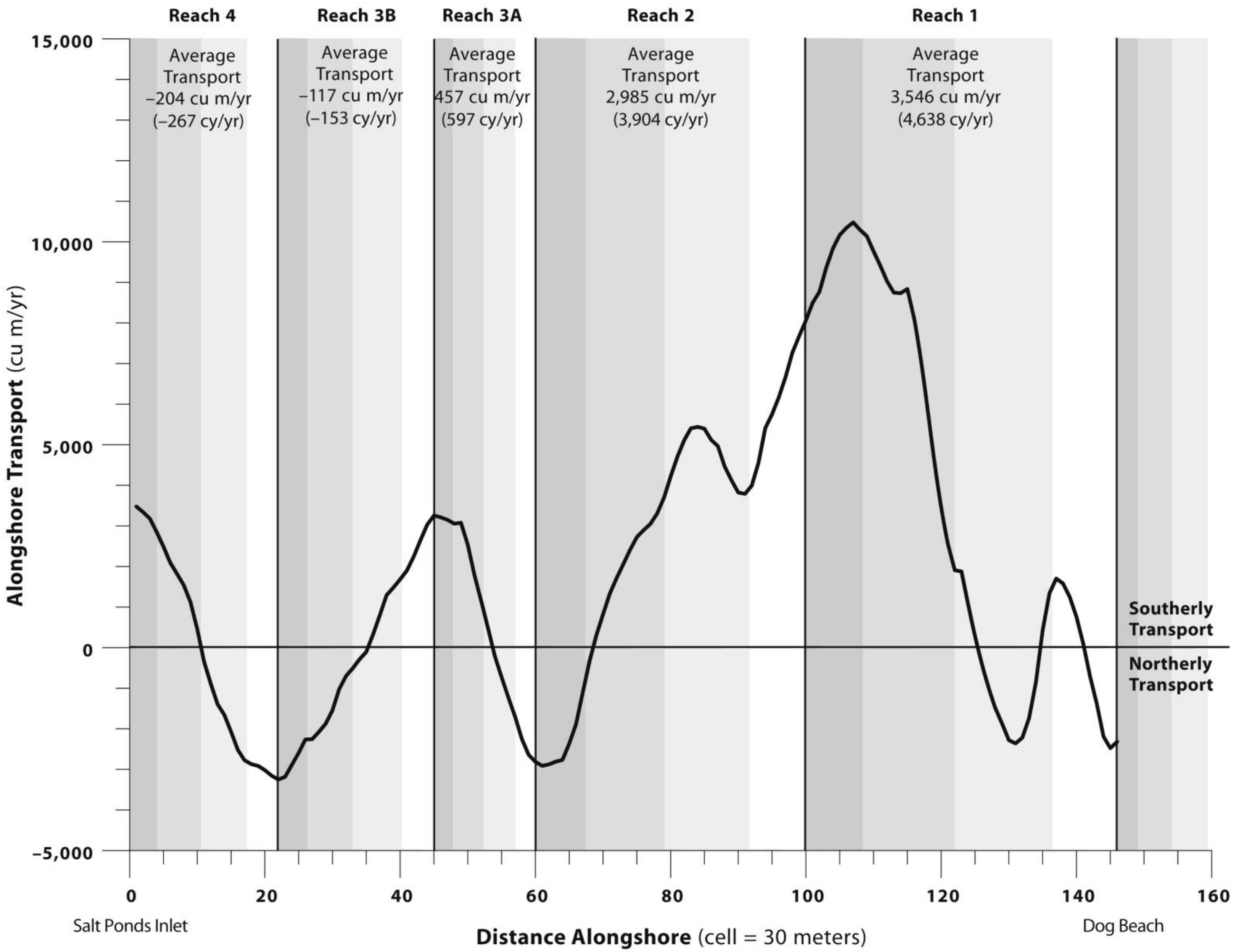


Figure 3-6A: Longshore transport potential for Reaches 1 to 4 (Fort Monroe to Salt Ponds Inlet).

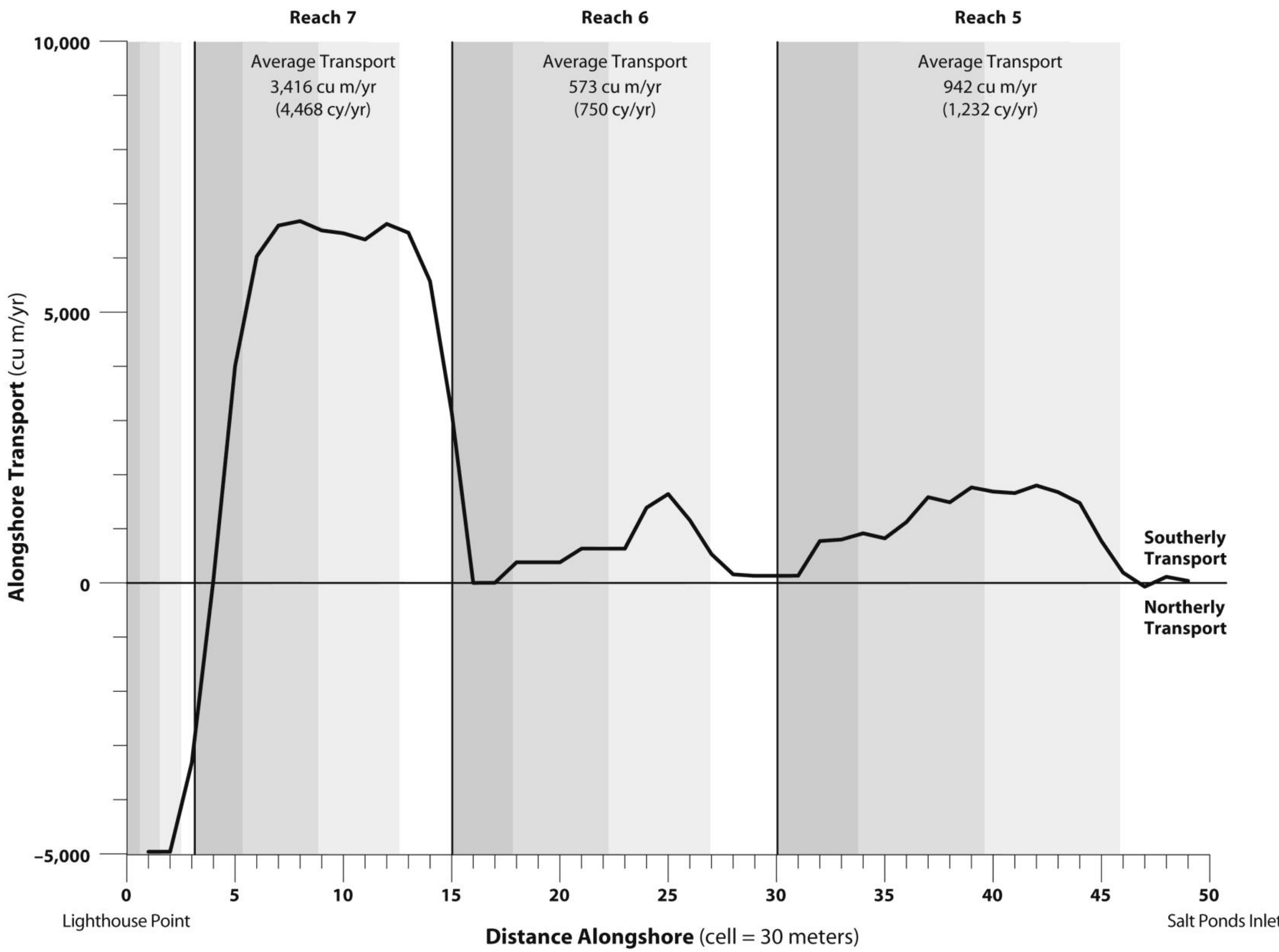


Figure 3-6B: Longshore transport potential for Reaches 5 to 7 (Salt Ponds Inlet to Lighthouse Point).

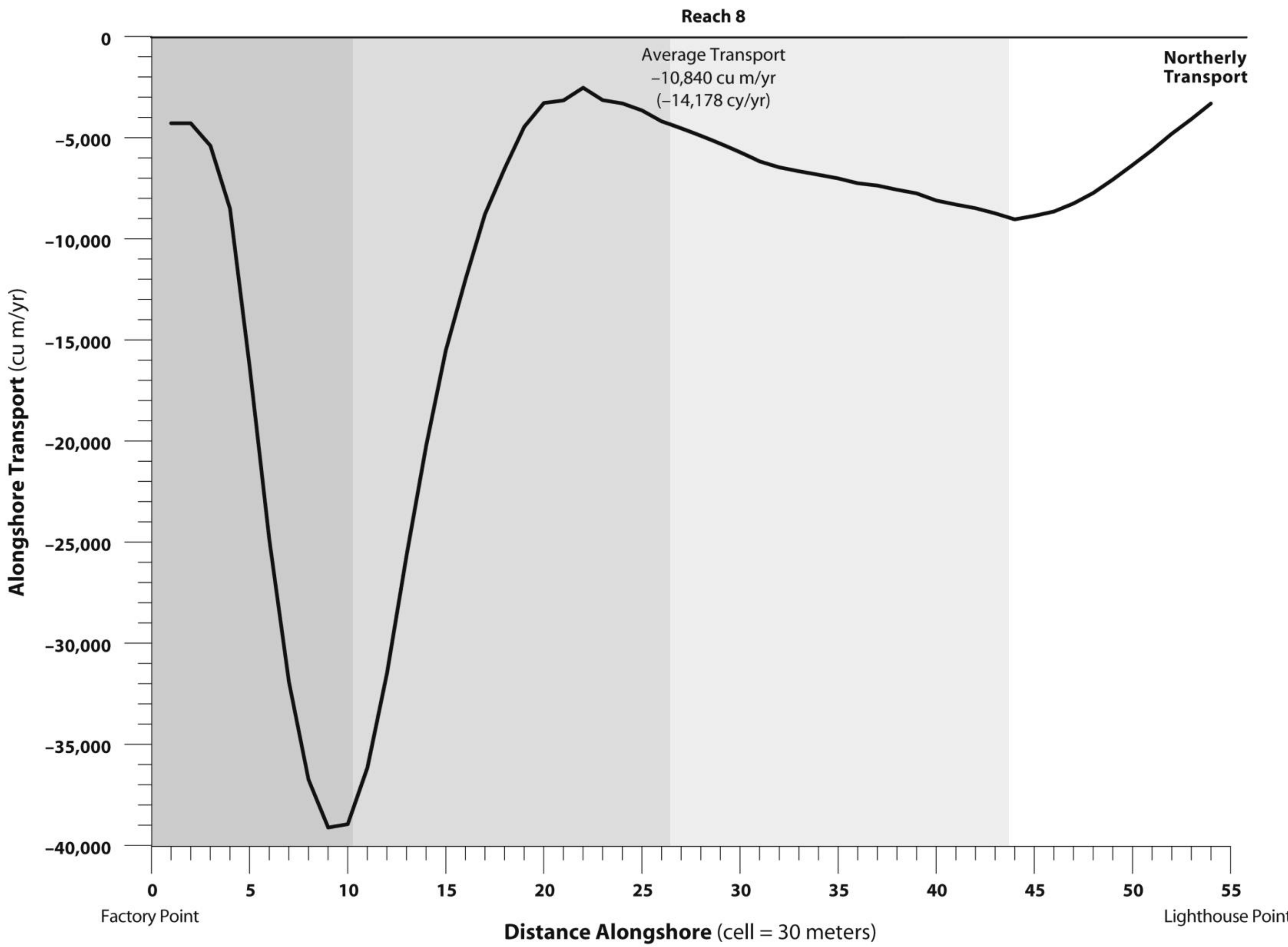


Figure 3-6C: Longshore transport potential for Reach 8 (Lighthouse Point to Factory Point).

3.4 Storm Erosion Modeling (EDUNE)

The most dramatic changes in the Hampton shoreline typically result after storms. These storms not only cause flooding, but often destroy buildings and infrastructure sited too close to the shoreline. In management planning, it is important to understand the long-term evolutions in the shoreline, but also evaluate the magnitude of short-term impacts due to storms.

Storm erosion modeling has been conducted as part of the Management Plan to determine the shoreline and dune recession resulting from 10-yr, 50-yr and 100-yr storm events. The EDUNE model is a numerical, computer model that has been used to assess storms along the Hampton shoreline. The following narrative provides a summary of the model and its results.

3.4.1 Background

EDUNE is a dune erosion model developed by David Kriebel, PhD (Kriebel, 1989) that is based on the equilibrium beach profile theory. The premise of this theory is that equilibrium formations or profiles are the result of the uniform dissipation of wave energy per unit volume in the surf zone. The theory suggests that a beach profile will always respond toward a stable equilibrium form relative to a given water level and wave height. An increase in water level during storms allows waves to break closer to the shore and there is an increase in the energy dissipation, which then becomes greater than its typical “equilibrium” profile or shape. As a result of the increased energy, the profile adjusts towards an equilibrium condition for that system and there is a redistribution of sediment from the beach and dune system toward the offshore. The EDUNE model assumes that the total sand volume across the beach profile is conserved and that there are no gradients in the longshore transport.

Historical tide records were evaluated to determine return intervals on high water levels at the Sewells Point tide gage. In addition, other published storm frequencies were reviewed for validation. The EDUNE model results are based on the tidal elevation referred to as mean seal level (MSL) which historically falls between the MHW and MLW contours. In this study, it is assumed that the 100-yr storm is associated with a still water elevation of 7.5 ft MSL (7.8 ft NAVD), a 50-yr storm has a water elevation of 6.3 ft MSL (6.6 ft NAVD) and water levels reach 5.0 ft MSL (5.3 ft NAVD) during a 10-yr storm event. (Note: these models were run on the previous tidal epoch. The 0.38 ft correction has not been applied to these results – therefore the return frequencies are slightly different than presented in Table 2-2 of this report.) VIMS performed an analysis of wave height distributions associated with the various tide elevations and return intervals. During a 100-yr storm, wave heights of 10 ft are expected, while breaking waves of 8 ft and 6 ft were associated with the 50-yr and 10-yr events, respectively. Each of the conditions were modeled for a 24 hour storm period using beach profiles that were surveyed along the Hampton shoreline in July of 1997.

EDUNE was not used to model conditions at Grandview or the Nature Preserve. Since a sandy beach does not exist along Grandview, the beach profile cannot equilibrate during storm conditions. As a result, the model could not be applied along this reach. Grandview Nature Preserve is characteristically low and is overtopped by the smallest of storm conditions. EDUNE does not accurately model low profile, spit beaches.

3.4.2 EDUNE Results

3.4.2.1 Reach 1 (Fort Monroe and Thimble Shoals Court)

Figure 3-7 provides the dune erosion model results for Fort Monroe. The 7.0 ft MSL contour is used to determine the recession for comparative purposes between storms. Model results showed that the 7.0 ft MSL contour eroded 40 ft as a result of the 10-yr event, 80 ft during the 50-yr event and more than 105 ft from the 100-yr storm. The combined storm tide and breaking waves do not completely overtop the dune structure during the 10-yr event. Both the 50-yr and 100-yr storms overtop the dune and lower its elevation. As a result, the existing dune system would not protect upland buildings and infrastructure during these two events. This is not necessarily a problem along Fort Monroe since the access road to the beach is the only major infrastructure in the vicinity of the shoreline. There are, however, several homes along the shoreline north of Fort Monroe at Thimble Shoals Court that would be impacted during a 100-yr event, and possibly a 50-yr storm.

3.4.2.2 Reach 2 (Buckroe Beach - Public)

A protective bulkhead fronts the entire shoreline along Reach 2. EDUNE models this condition as a vertical wall, but does not indicate when or if the structure fails. Since the bulkhead provides a landward boundary condition, storm impacts will be assessed by the lowering of the beach planform in front of the wall. For this evaluation, it is assumed that the top of the bulkhead is approximately 10 ft above MSL and the second set of wales is located at an elevation of about 3 ft above MSL. If the beach is lowered more than a foot below the second wale, the bulkhead fails.

Figure 3-8 depicts the dune erosion model results for Buckroe Beach. During the 10-yr storm event, the bulkhead is not overtopped and it does not immediately fail. Waves will definitely overtop the bulkhead during the 50-yr and 100-yr events. The bulkhead may survive the 50-yr event, but will most likely fail during the 100-yr storm. It is important to note that after the twin nor'easters, there was a slight lowering of the beach in front of the bulkhead, but not nearly to the level modeled for the 10-yr storm event. Therefore, the EDUNE model results for the smaller storm events at Buckroe Beach are extremely conservative. This is probably because the water elevations were high during the twin nor'easters, but breaking wave heights never reached 6 ft. The results show, however, that a protective berm fronting a vertical structure reduces the reflected wave energy minimizing damage.

3.4.2.3 Reaches 3 and 4 (Malo Beach and Salt Ponds)

The characteristic shoreline and development along Reaches 3 and 4 varies significantly. In July, 1997 when the beach profiles were surveyed for this study, there was a protective dune structure along Reaches 3A and 4. After the twin nor'easters, the dune system at Salt Ponds was badly damaged and receded in excess of 25 ft at some locations. Various revetments and bulkhead, as well as a geotube structure were later constructed to replace the eroded dune and to protect the private residences. Reach 3B is characterized by a low and narrow berm backed by an assortment of interspersed bulkheads and revetment. Therefore, Range 10, the typical profile selected to represent this section of shoreline, is not characteristic of the conditions along Reach 3B.

Figure 3-9 depicts the EDUNE model results for Salt Ponds and south Malo Beach. The height of the original dune exceeded 9.0 ft MSL. The 7.0 ft MSL contour is used to determine the dune recession for comparative purposes between storms. Model results showed that the 7.0 ft MSL contour eroded 50 ft as a result of the 10-yr event, 85 ft during the 50-yr event and 120 ft from the 100-yr storm. The modeled storm tide and breaking waves appear to overtop the dune structure during all three events.

When compared to the actual dune erosion rates experienced at Salt Ponds after the twin nor'easters, the model results once again appear extremely conservative for the smaller storm event. Although the model results are not directly applicable to Reach 3B, it is apparent that even the smaller storms with frequencies less than 10 years will cause damage to protective structures and buildings. There is no protective berm or dune to buffer the wave energy. The homes along Reach 3A and at Salt Ponds should not be damaged during a 10-yr storm, but will more than likely be impacted by the 50-yr and 100-yr events.

3.4.2.4 Reach 5 (White Marsh)

Range 18 is located at the northern extent of White Marsh. The profile surveyed in July of 1997 depicts a low-lying, narrow berm dune. Figure 3-10 provides the EDUNE model results for White Marsh. All three storm events completely overtop the dune structure. The top of the dune will probably be removed during the 10-yr event and the 7.0 ft MSL contour is predicted to recede 60 ft. The 50-yr and 100-yr events will essentially destroy the dune system and could possibly form a breach along this section of shoreline. Both storms associated with the twin nor'easters did in fact overtop the island and damaged the dune system.

It is difficult to assess storm impacts for Reach 5 since there are no structures along the White Marsh shoreline. A breach at White Marsh, however, will affect the hydraulics at Long Creek which could potentially have an impact on the stability of Salt Ponds Inlet.

3.4.2.5 Reach 6 (Grandview)

As previously mentioned, the EDUNE model is not applicable along the Grandview reach. The model results, however, show that the dunes in the northern reaches are overtopped during the smaller storms or 10-yr events. Much of the revetment and existing bulkhead along Grandview has been damaged by previous storms and are in various states of disrepair. Moreover, there is no protective berm to buffer the protective structures from breaking waves making this one of the most vulnerable reaches to storm impacts.

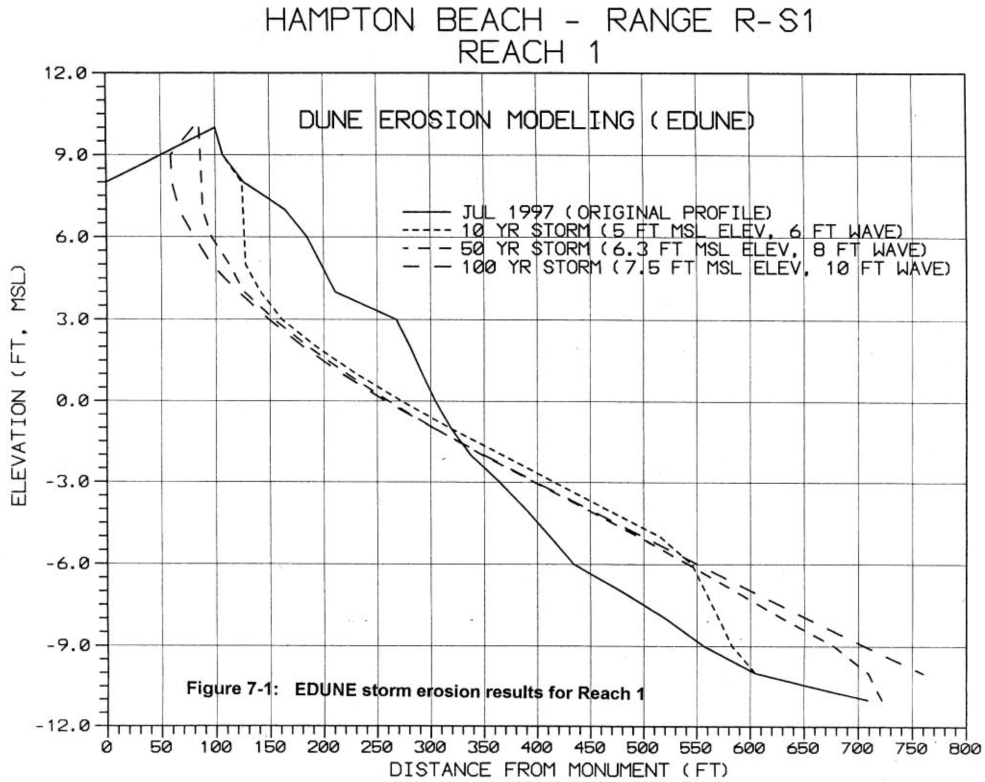


Figure 3-7: Dune erosion modeling results (EDUNE) for Reach 1 (Fort Monroe and Thimble Shoals Court).

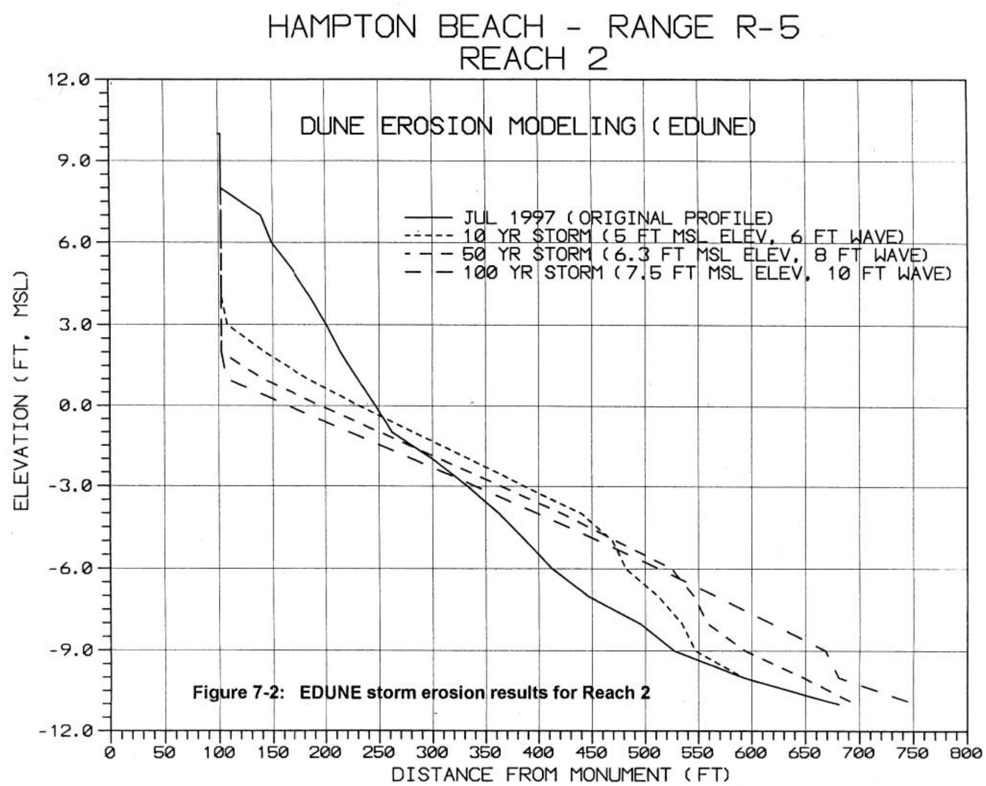


Figure 3-8: Dune erosion modeling results (EDUNE) for Reach 2 (Buckroe Beach).

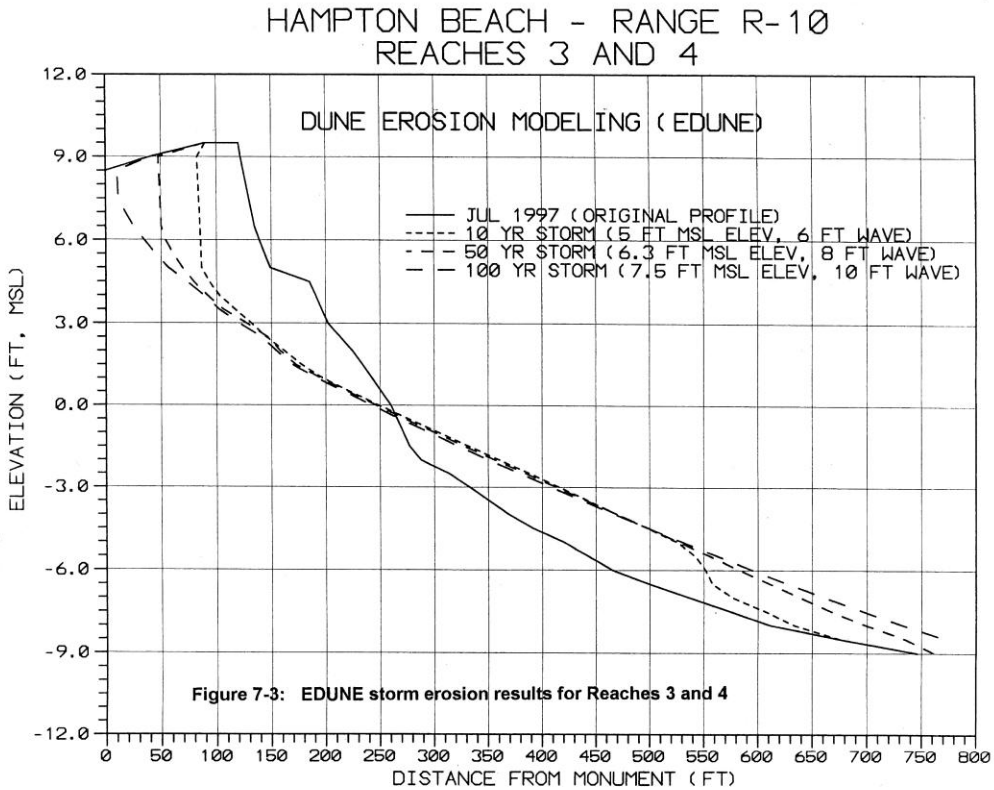


Figure 3-9: Dune erosion modeling results (EDUNE) for Reaches 3 and 4 (Malo Beach and Salt Ponds Beach).

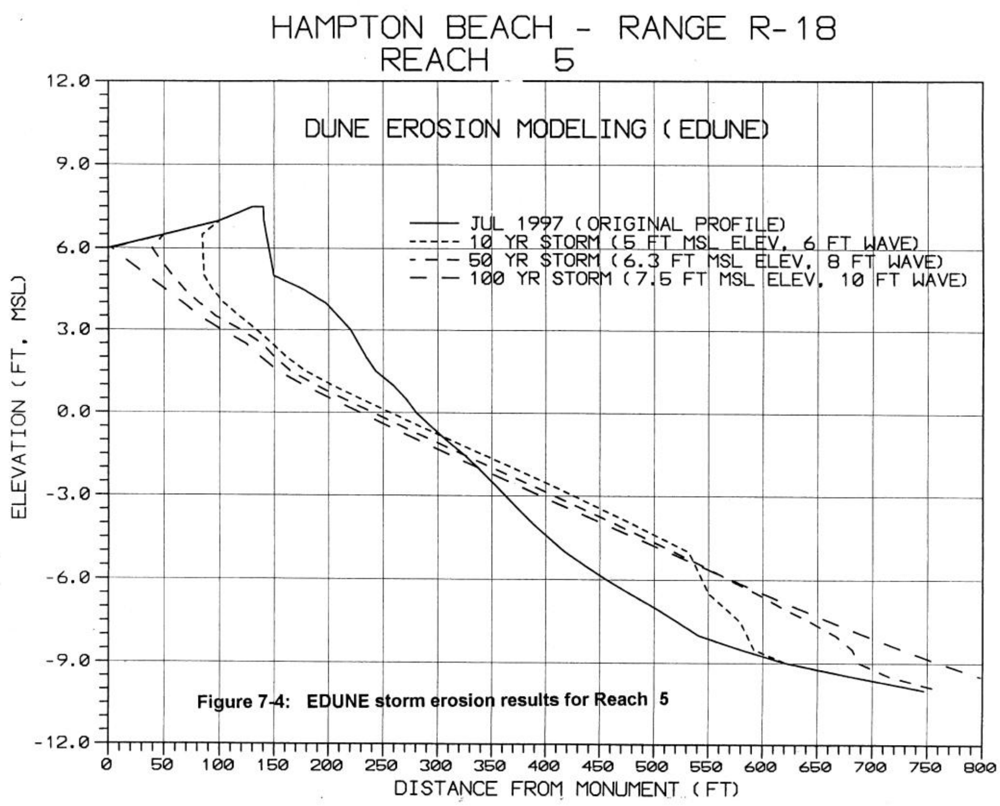


Figure 3-10: Dune erosion modeling results (EDUNE) for Reach 5 (White Marsh Beach).

4.0 SHORELINE PROTECTION ALTERNATIVES

Shoreline protection can be classified into two main categories including shoreline defense mechanisms and process altering structures. Shoreline defense mechanisms are often used to “hold the line” or prevent damage to upland properties. The two categories of shoreline defense mechanisms are often referred to as “soft” and “hard” structures. Soft defense structures include beach renourishment, dune construction and possibly the implementation of living shorelines, while hard structures include vertical bulkheads and seawalls, as well as rock revetment and gabion structures. Process altering mechanisms are those structures that are designed to change the natural coastal processes for a specific desired affect and would primarily include groins, breakwaters and jetties. In many cases, a composite alternative or a combination of process altering and shoreline defense mechanisms provides the best strategy for comprehensive, long-term coastal zone management. A comprehensive shoreline management plan must also consider the “do nothing” alternative. For some areas, shoreline retreat may be the most cost effective or practical solution.

The goal, for effective beach management, is to balance the project performance, cost and minimization of adverse impacts with each design recommendation. In many cases, more than one strategy or a composite project may best suit the long-term goals for various shoreline segments.

The following section describes common shoreline protection methods. The discussion for each method provides a brief description, relative cost, and general applicability to the Hampton shoreline. *Structural designs have not been completed for the alternatives; therefore costs are provided only for comparative purposes.*

4.1 Beach Renourishment

Beach renourishment is the process of restoring a shoreline by adding sand to the area in order to increase the height and width of the berm. (Figure 4-1 provides a simple cross-section schematic.) It is a form of soft shoreline protection and has become more popular over the past forty to fifty years in an effort to reduce the number of hardened structures along the beach and to restore sand to the littoral system. An additional advantage of beach renourishment is that adverse impacts to adjacent or upland properties are negligible and typically environmental impacts are minimal. The primary environmental concern within the Chesapeake Bay would be to insure that the renourishment project would not impact subaquatic vegetation (SAV) or cover essential fish habitat (EFH), affect threatened or endangered species such as the tiger beetle and that there is minimal silt and clay (fines) in the placed material to reduce adverse impacts on water quality.

The City of Hampton has constructed beach renourishment projects at three locations along the public shoreline. The first project was the public beach at Buckroe which was built in 1990 and restored in 1996. The federal project at Buckroe Beach and the “betterment” project at Salt Ponds Beach were constructed during the winter of 2005. Salt Ponds is periodically renourished approximately every two years with sand dredged from the Salt Ponds Inlet. More recently (2010), the breach at Factory Point in Back River was restored as a beach renourishment project using the sandy material just offshore from the project location.

The costs for beach renourishment vary greatly depending on the location of the source of material, the size of the project and the availability of dredges. The source of the sand for beach renourishment projects constructed along Buckroe and Salt Ponds has been Horseshoe Shoals which is sited about two miles offshore from the placement area. While the shoal provides good quality beach material, there are concerns with ordnance in the borrow area. Due to the additional costs of ordnance detection and removal, the costs of “in place” beach fill along the Hampton shoreline have ranged from about $7.50/cy to more than $10/cy. The cost is significantly affected by size of the project (economy of scale), the proximity to the borrow site (size of the dredge and/or boosters required to pump the material) and regulatory constraints such as ordnance detection and removal, impacts to threatened and endangered species (tiger beetle and some nesting shorebirds), time of year restrictions and potential loss of essential fish habitat.

Beach renourishment performs best in low to moderate erosional environments and can also be designed with structures to help stabilize the project. Continued beach renourishment is essential to effective shoreline management. Due to the cost of beach renourishment and regulatory constraints, it is typically not a practicable alternative along privately owned shorelines. (Without easements, it is difficult to permit a beach renourishment project along private shorelines since all owners would have to agree to the project and then the agencies would have to determine that the project was in the public’s best interest.) An ancillary benefit to beach renourishment is that in addition to storm protection, it can provide recreational amenities and improve water quality by filtering stormwater runoff before it enters the Bay.

4.2 Sand Dunes

Sand dunes are a natural or manmade mound of sandy material that separates the active beach from the upland environment (see Figure 4-2). They are a physical barrier to storm waves and contain a reservoir of sand that nourishes the beach as they erode. As a result, sand dunes offer some protection for upland properties and infrastructure during storms and are typically considered “soft shoreline stabilization.” Dune systems, however, can also be constructed with hardened cores or centers such as rock or “geotubes.” Constructing a dune system with a hardened core increases the level of storm protection for upland properties, while still providing the aesthetics of a natural environment.

Low-level sand dunes currently exist along Dog Beach in Fort Monroe, and along the southern portion of Malo Beach. Additional dune systems of varying height are located at Salt Ponds, White Marsh and the Grandview Nature Preserve. The bluff system at Salt Ponds is a manmade feature and is the highest of the dune/bluff structures along the Hampton shoreline. In 1998, the dune system at Salt Ponds was reconstructed using sand filled geotubes as the core for the project. The geotubes were then covered with sand and planted with American beachgrass for stability. The dunes at Salt Ponds range in height from approximately 5 ft to 9 ft above the beach berm. The dunes throughout White Marsh and Grandview are low profile dunes, which are frequently overtopped during storms.

There is not much detailed information for dune construction costs along the Hampton shoreline. Dune construction is slightly less expensive than conventional "hard" shoreline protection alternatives. The cost depends on the size of the dune, site accessibility, sand source and availability of plant materials. A price range of $25 to $30/cy is a realistic estimate for construction of a vegetated dune if the sand is truck hauled to the site. The cost is much less if the dune is constructed as part of a beach renourishment project and the sand is hydraulically pumped to shore. Then the cost may be on the order of $15/cy. A 6-foot sandy dune structure with 1:3 side slopes would cost on the order of $175 to $200 per foot if the sand is hauled and less than $100 per foot if the material is hydraulically pumped to the site. Creating a dune with a hardened core increases the cost according to the type of construction materials used for the core and the level of difficulty in constructing it.

Dunes are a form of soft shoreline stabilization that provide a buffer against storm impacts and also offer a barrier or degree of privacy between the public beach and private areas. Dunes perform best when there is a sandy beach fronting the system. Dune enhancement is a viable shoreline management tool along the northern end of Fort Monroe, portions of Malo Beach, White Marsh Beach and the Grandview Nature Preserve. It is not generally a viable management practice along individual private residences due to cost and the limited effectiveness for directly protecting upland structures.

4.3 Vertical Bulkheads and Seawalls

A bulkhead or seawall is a structure designed to protect the bank or dune and upland infrastructure (see Figure 4-3). Bulkheads are designed to retain upland soils; whereas, seawalls are more substantial structures designed to protect the uplands from the direct impacts of waves. The two terms are often used interchangeably for vertical structures.

Bulkheads and seawalls can be constructed of various materials including timber, metal sheetpile, plastic polymers or reinforced concrete. They typically consist of the main wall feature in which the toe is placed below the ground surface to a design elevation lower than the projected scour. The anchoring and tieback system provide the strength to the wall. Failure is often the result of improper anchoring that cannot withstand the increase in backpressure during high-energy wave events. If there is not enough distance behind a bulkhead or seawall for a proper tieback system, knee bracing on the seaward side is often used to provide stability.

As waves hit bulkheads or seawalls, the energy is either transferred horizontally across the face of the structure, vertically along the structure, or reflected back from the wall. It is important to note that while vertical seawalls and bulkheads protect upland structures, they can also be responsible for shoreline erosion. As vertical structures reflect wave energy, sand can be transported offshore resulting in an overall lowering of the beach in front of the structure.

Currently, a timber bulkhead structure with a reinforced concrete cap is located along the public beach at Buckroe from south of Old Point Comfort Avenue to Pilot Avenue. The bulkhead also supports a concrete walkway, which serves as a boardwalk. The bulkhead along the public beach provides protection for upland infrastructure and provides a platform for recreation as well. Due to the wide protective beach currently fronting the bulkhead, waves only impact the structure during severe storm events. As a result, this structure does not currently have an adverse affect on the fronting beach.

Several other bulkheads have been constructed along the private residences at Thimble Shoals, Malo Beach, as well as at Salt Ponds and Grandview. The bulkheads at Grandview and along the private sections of Malo were constructed as far back as the early 1960's; whereas the bulkheads along Salt Ponds were constructed during the 1990’s. There are currently no City design standards for vertical bulkheads, and as a result many function more as retaining walls.

According to NOAA Seagrant (2007), the cost for vinyl and timber bulkheads ranges from about $115 to $285 per foot. That price range is applicable for residential bulkhead costs along the various reaches of the Hampton shoreline. A $2,500 to $4,000 per foot estimate is typical for local commercial reinforced concrete or steel sheetpile bulkheads and would be more in line with the cost of replacing the existing structure along Buckroe Beach.

Bulkheads are a defense strategy to prevent damage to upland investments and as such are a necessary component of many shoreline management programs. Bulkheads and seawalls can also protect upland property from flooding and therefore are considered as important management strategies along private property. Vertical structures, however, can accelerate shoreline erosion and should be designed and constructed to minimize impacts to the surrounding environment.

4.4 Rock Revetment

Similar to seawalls and bulkheads, rock revetment is constructed along the eroded shoreline or bank to prevent additional loss of land and protect upland infrastructure. The advantage to a sloping rock revetment is that it tends to absorb and dissipate wave energy. As a result, erosional impacts to adjacent property and the toe of the structure are significantly reduced as compared to vertical walls. Rock revetment can be constructed out of various types of building materials including quarry stone, broken concrete rubble and pre-fabricated interlocking forms (see Figure 4-4).

Rock revetment currently exists throughout the Hampton shoreline, in particular along the beaches at Salt Ponds and Grandview, as well as numerous properties along Hampton's tidal tributaries. This type of structure is used to prevent shoreline retreat. Improperly designed revetment, however, can have a negative impact on the beaches. Using undersized stone or unsuitable building materials for the revetment will significantly reduce the structural integrity and the revetment will have a greater potential for failure during storm conditions. Failed revetments litter the beach with debris causing hazardous conditions for pedestrians and swimmers and can damage structures.

The cost of rock revetment depends on the size of the structure, weight of stone, accessibility to the site and availability of material to the site. An estimated cost of $75 to $90 per ton provides a working estimate for the cost of revetment in lower energy areas. Larger structures with heavier stone may be required for higher energy areas and the cost for revetment may be a little higher.

Properly designed revetment can be an acceptable alternative to stopping shoreline retreat in many instances along both the private and public reaches of the Hampton shoreline. It can also be used as the core material for dune projects or in conjunction with beach renourishment projects.

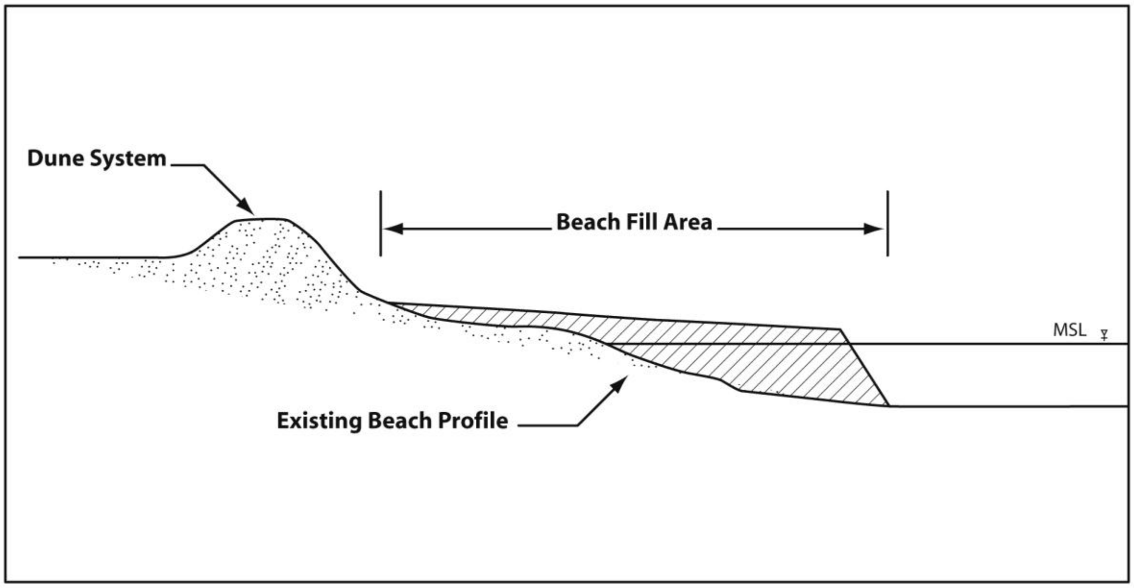


Figure 4-1: Cross-section of a typical beach renourishment project.

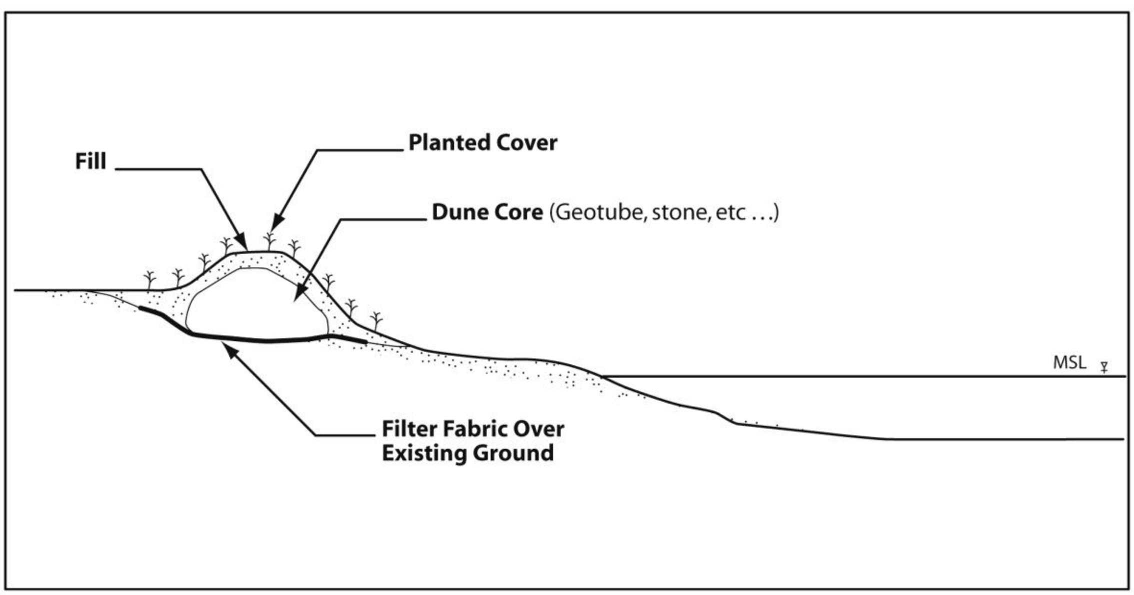


Figure 4-2: Cross-section of a dune restoration project. This particular cross-section has a core.

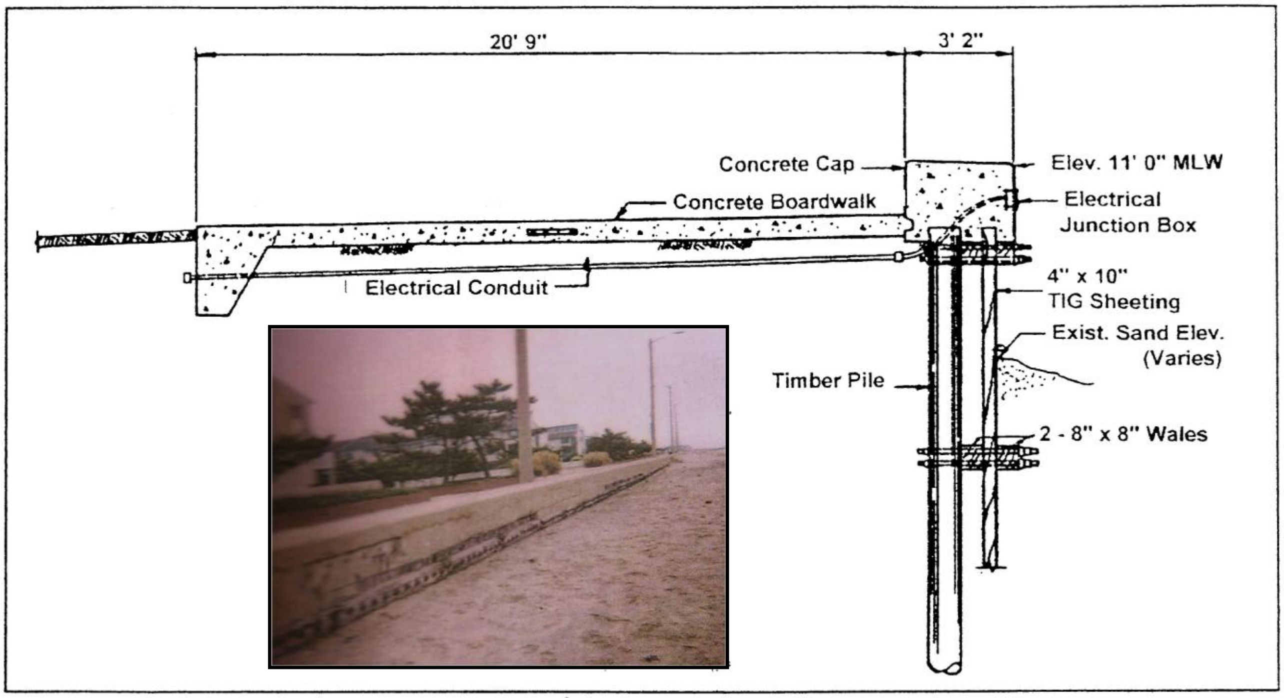


Figure 4-3: Cross-section of the bulkhead at Buckroe Beach (From Espey Huston et al, 1988).

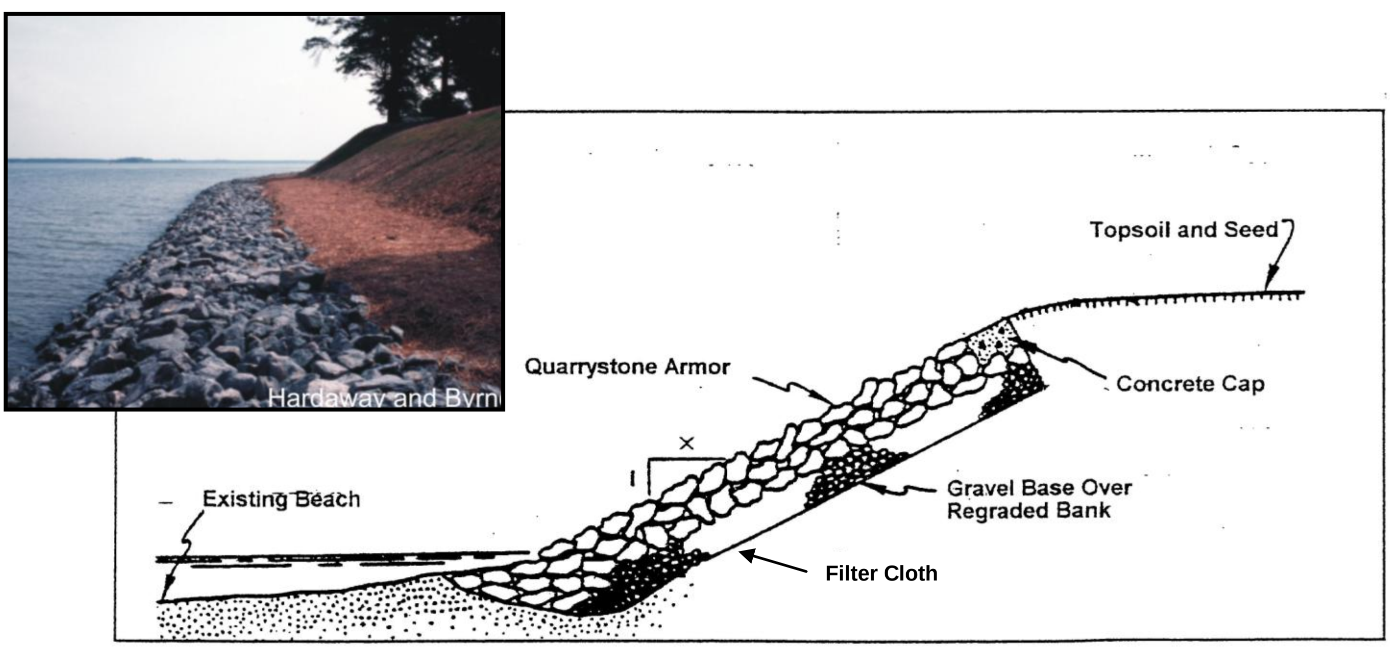


Figure 4-4: Cross-section of a typical rock revetment (Hardaway and Byrne, 1999).

4.5 Groins

A groin is a structure that is perpendicular to the shoreline and extends channel-ward from at least the elevation of mean high water (MHW) to a depth greater than mean low water (MLW). Groins raise the level of the beach by trapping the sediment that is transported along the shore or parallel to the beach. Sediment movement along the shore is referred to as longshore or littoral sediment transport. As the littoral sediment transport is interrupted by the groin, a fillet is formed on the updrift side of the structure and a depression or lowering of the beach forms on the downdrift side. As a result of this process, groins are often constructed in a series, typically referred to as a groin field. Figure 4-5 shows a plan and cross-sectional view of a typical groin along Buckroe.

There are two primary drawbacks to the use of groin fields for shoreline protection. The first drawback to this type of shoreline protection is that in order for a groin field to trap sediment, there must be sediment moving within the littoral system. Therefore, if a project area is sediment starved or if there is a weak littoral current, then the groin cannot effectively trap sediment. In such a situation, a groin field works best in conjunction with beach renourishment. The second drawback is that since the purpose of a groin field is to interrupt the littoral sediment transport, there is generally an adverse impact at some location on the downdrift shoreline. Groins do not really directly reduce wave energy and they do not prevent flooding.

There are currently twenty-four groins located between the northern extent of the Fort Monroe seawall and Salt Ponds Inlet. These groins range from 290 to 320 feet in length. Three rock groins are located on Fort Monroe at Dog Beach; three timber groins are located along the private beach at Thimble Shoals; seven timber groins are located along the public portion of Buckroe Beach, six timber groins exist along Malo Beach; three timber groins are sited along the public beach at Salt Ponds, one is located in White Marsh and a minor structure exists along Grandview. The rock groins at Fort Monroe are higher than the timber groins and appear to be functioning well in terms or trapping littoral sediment. The timber groins were constructed during the late 1960's to help stabilize the shoreline after the damaging effects of the Ash Wednesday Storm of 1962. These groins are relatively low profile structures and have not been maintained. As a result, they are in various stages of disrepair and are currently at the end of their functional design life.

Preliminary estimates on groin replacement for the timber structures at Buckroe Beach proposed a cost of $350 to $450 per linear foot of structure. Therefore, the approximate cost for replacing a single 300-foot timber groin structure may range between $105,000 and $135,000. Due to the age of the structures and the various conditions, it is not feasible to provide estimates for structural repairs.

The Hampton shoreline is a sediment-starved littoral system. Due to the hydrodynamic nature of the system, the groins have provided only moderate protection, but they continue to have some impact on the longshore transport. The cost to replace the structures is somewhat prohibitive, especially when considering the potential for adverse downdrift impacts and their limited effectiveness as a shoreline protection method along the Hampton shoreline. Modification of the existing structures with breakwaters may prove beneficial. The breakwater at Buckroe Avenue was constructed in conjunction with an existing groin and has performed extremely well. Groin fields are not recommended along the private reaches of shoreline throughout Hampton's tributaries due to the resultant downdrift impacts of the structures.

4.6 Breakwaters

Breakwaters are designed to dissipate wave energy before it reaches the shoreline, thereby protecting the upper reaches of the adjacent beach from the direct impact of breaking waves. They are constructed offshore with crest elevations typically above MHW and parallel to the shore or perpendicular to the design wave direction. Breakwaters are usually constructed of quarry stone and designed as a series of structures along the shore, depending on the length of the project area. In general, the higher a breakwater is constructed, the more effect it will have on dissipating the larger waves generated by storms. Breakwaters are process altering structures and while they help protect the uplands by reducing wave energy, they do not reduce coastal flooding. Figure 4-6 depicts a typical breakwater design along the Hampton shoreline.

Examples of successful breakwaters are located throughout the Chesapeake Bay including Ocean View in Norfolk and Anderson Park in Newport News. These project sites are close in proximity to the Hampton shoreline and experience similar coastal processes. In October of 2001, the first breakwater was constructed along the Hampton shoreline at the end of Buckroe Avenue and in April of 2010 a second breakwater was completed at Point Comfort Avenue. Based on the results of previous modeling, a third breakwater is planned for construction in the vicinity of Pilot Avenue in 2011.

The price per linear foot of structure is dependent on the size, availability of material, difficulty in placing the stone, access to the site and number and/or length of structure (i.e. economy of scale.) Recent costs for local breakwaters ranged between \$100 to \$120 per ton.

Breakwaters can be successfully designed as "T Heads" or shorter attached structures to the existing groins, as a series of structures along the shore, or as a single, strategically placed structure. Breakwaters can also be designed in conjunction with beach renourishment projects to help extend project life. These structures offer an extremely viable means of shoreline protection throughout Hampton, though the cost may be prohibitive for individual residents.

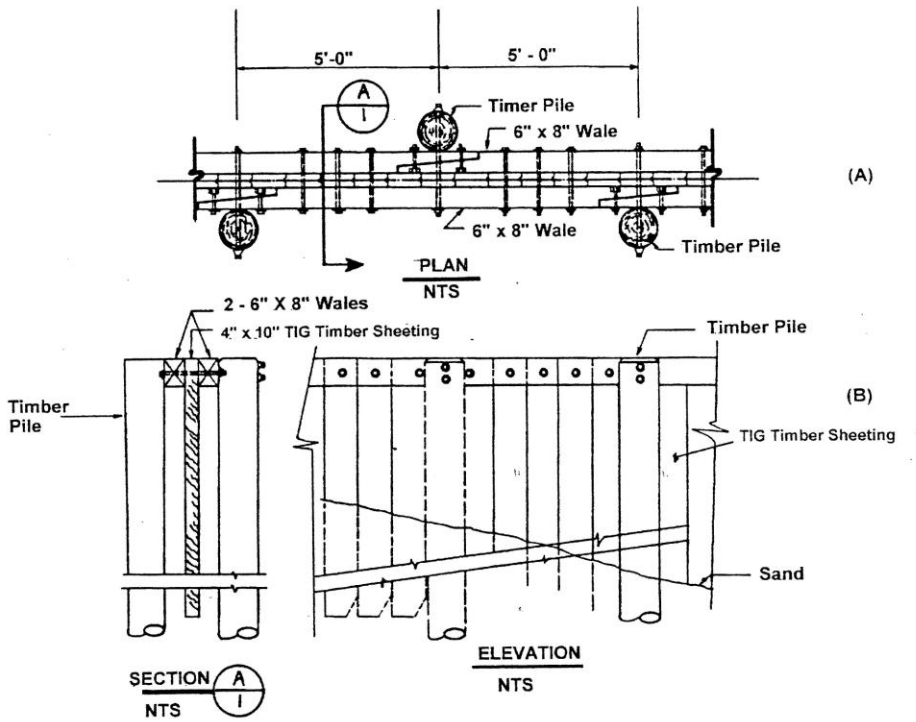
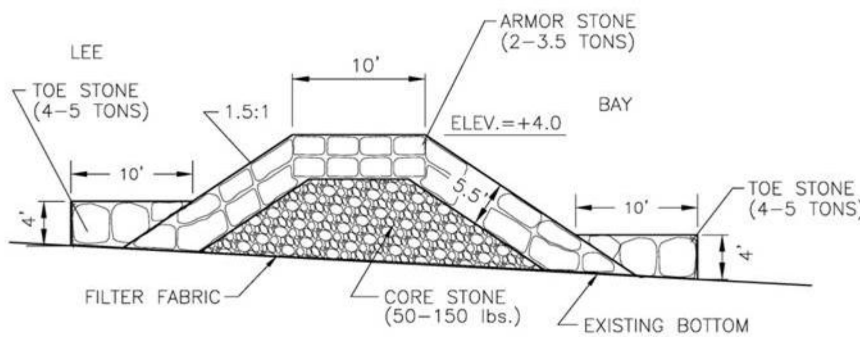


Figure 4-5: Cross-section of a typical groin at Buckroe Beach (from Espey Huston, et al, 1988.)



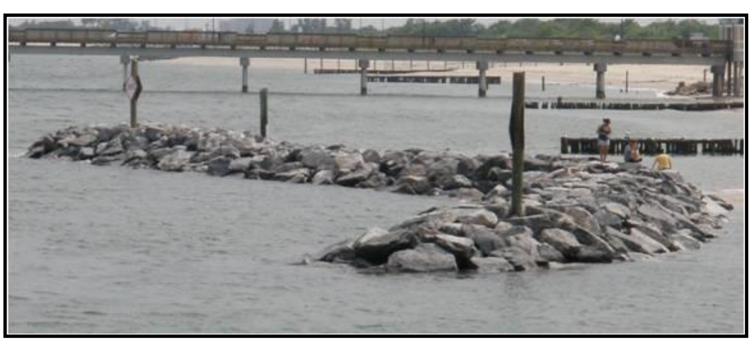


Figure 4-6: Cross-section and picture of a typical breakwater at Buckroe Beach.

4.7 Jetties

Jetties are similar to groins, except that they are used to stabilize inlets. They are typically much higher in elevation and extend further into the nearshore in order to prevent the inlet channel from shoaling and to direct and confine tidal flow through an inlet. Jetties can be constructed of timber, sheetpile, concrete or rock and are designed to trap the littoral drift and its sediment load before it enters the inlet. As a result, there is a fillet or accumulation of sand on the updrift side of the inlet and a deficit of sand on the downdrift side. (Figure 4-7 shows the jetty structures at Salt Ponds Inlet.)

Cost estimates for jetties are extremely variable and are dependent on the working conditions, the design dimensions, as well as the building materials. Preliminary estimates for the construction of a rock jetty with a sectional height of 8 ft and a crest width of 20 ft is between $2000 to $2500 per linear foot. Timber or sheetpile jetties are less expensive, however, they have a shorter life, reflect wave energy and require more maintenance than rock jetties.

Two jetties are located at the mouth of the Salt Ponds Inlet for stabilization. The south jetty was re-constructed in 2005 and is a sheetpile structure. Sand often enters the inlet around the jetty during southerly swells. The northern jetty is a much larger rock structure which is slightly curved to the south. The north jetty is approximately 500 ft in length and while in overall good condition, it appears to leak sand. This jetty is also fairly low in profile and is overtopped during northeaster storms. The jetties do not adequately prevent shoaling inside the inlet and maintenance dredging is required approximately every eighteen months to two years to remove sediment from the channel.

Jetty improvements at Salt Ponds Inlet will help reduce the amount of dredging required to maintain the channel and prevent sand from future renourishment projects from shoaling in the inlet.

4.8 Geotubes or Geotextile Technologies

Geotubes consist of a tube or bag constructed of some type of geotextile fabric that is filled with either silt, sand or jetted concrete**.** The tubes vary in size from small sand bags to tubes that can exceed 200 ft in length with circumferences of 25 to 30 feet. Geotubes can be used as either groins or as a retaining wall in low energy environments. More recently, geotubes have been used as the core material for dune construction projects and to create perches for wetlands and beaches. The associated construction costs are much less than similar structures that use quarry stone and are often easier to place and fill. The disadvantage is that they are unsuitable for higher energy environments. Additionally, the tubes are susceptible to ultraviolet degradation, tearing and are vulnerable to acts of vandalism. If repairs are not made immediately, then the integrity of the structure is quickly lost.

A geotube project was constructed along the Salt Ponds public beach during the summer of 1998. Approximately 2,000 ft of geotube structure (200 ft long tubes with 30 ft circumferences) were filled with dredged material from Salt Ponds Inlet. The geotubes were designed to form the base of a dune feature that would provide protection of the existing banks and infrastructure from future storm damage (Figure 4-2). In the fall of 1998, the geotubes were covered with sand and sprigged with American beachgrass for stabilization. The geotube performed extremely well during Hurricane Isabel. Sections of the tube were damaged, but repaired in 2004. Since the placement of the geotube, there have not been any wave damages from storms to homes along Salt Ponds Beach.

The cost for geotubes and other geotextile structures varies significantly depending on the manufacturer, the size of the tubes, and the number purchased. Reasonable estimates for filled geotube structures are on the order of $250 to $350 per foot.

Geotubes can provide relatively low cost shoreline stabilization in the form of bank protection and can be used throughout various sections of the Hampton shoreline for this application, especially in conjunction with dune construction projects. Geotubes have been used in other areas to build groins and breakwaters; the success of these projects has been dependent on the environment.

4.9 Gabions

Gabions consist of rectangular, wire mesh baskets filled with small quarry stone. They can be stacked on top of each other or laid end to end in order to construct breakwaters, groins, or revetments. The advantage is that each empty basket is first placed in its proper orientation and then filled with stone. Since the placement area is contained and the stone is small, then large equipment is not required for construction. In many cases the structures can be placed and filled using only manpower. The obvious disadvantage to gabions is that they are only suitable for use in very low energy environments and the integrity of the structure is often destroyed once impacted by storm waves. The other disadvantage is that once the basket corrodes in the salt environment, then the integrity of the structure is also lost. If repairs are not made to the basket, then there is a safety issue or added liability due to exposed wires and litter.

Currently there are no gabion structures along Hampton's Chesapeake Bay shoreline. Gabions should only be used in low energy, low exposure environments. They often fail during high-energy events and then littler the beach with wire and stone.

These structures are much less costly than the more conventional methods of shoreline protection. A range of $25 to $75 per linear foot of structure is a typical construction estimate. This estimate does not include the costs associated with maintenance or repairs.

Due to the potential for liability and limited structural life, gabions are not recommended for use as shoreline protection along the Hampton shoreline. They may be a cost effective alternative along lower energy shorelines within the local tributaries

4.10 Nearshore Disposal

Nearshore disposal is a dredged material management practice where fine, marginal sand, is placed in low mounds, similar to a sandbar, just seaward of the active surf zone. It is considered a beneficial use of dredged material since it serves as a disposal method with the potential added benefit of wave energy reduction.

Nearshore disposal of very fine sand is not a common practice. It is highly regulated due to environmental constraints, impacts to the benthic environment, and potential adverse impacts to water quality. Moreover, its effectiveness is also questionable. Nearshore disposal of dredged material from Port Canaveral along Cocoa Beach was a common practice during the 1990's. It is no longer practiced since the material did not remain in the placement site long enough to provide any measurable benefit for shoreline protection.

Due to the environmental constraints and limited effectiveness as a viable method of shoreline protection, nearshore disposal is not recommended as a management strategy along the Hampton shoreline or for private residences.

4.11 Artificial Reefs

Artificial reefs consist of structures placed offshore from the beach to serve as breakwaters for dissipating wave energy. The reefs can be constructed of various materials including oyster shell, quarry stone or even strategically sunken barges and other vessels. The advantage of artificial reefs is that they can potentially reduce wave energy in local areas and with time they can develop into habitat for fish and other marine organisms. Disadvantages to artificial reefs can include the creation of hazardous swimming and navigation conditions, and possibly conversion of benthic marine habitat.

There are no set cost estimates for the construction of artificial reefs. The cost would be dependent on the building materials and the method of placement. A low level reef of oyster shell may cost between $45 to $55 per cubic yard, while other building materials would be much more expensive (NOAA, 2007).

Engineered artificial reefs constructed for shoreline protection do not currently exist in the Chesapeake Bay along the Hampton shoreline. The offshore area along Hampton is typically very shallow. In fact, water depths remain less than 15 ft below MLW for several thousand feet into the bay. The nearshore area is associated with recreational boating and swimming, as well as various commercial activities including crabbing and fishing. Therefore, the artificial reef would have to be clearly marked to reduce liability associated with swimming and navigation and would significantly limit those types of activities in the vicinity of the structure.

Abandoned vessels and barges have been used to create some artificial reefs in the offshore regions of the Chesapeake Bay. These reefs have been successful in creating habitat and attracting fish and other marine organisms. For an artificial reef to provide shoreline protection, however, it would have to be placed closer to shore, which could conflict with existing uses and still provide only minimal benefits.

The creation of artificial reefs, particularly with vessels and barges is not recommended as a shoreline protection alternative along the Hampton shoreline at this time. Oyster reefs and low profile sills are less expensive and can provide important habitat, and some shoreline protection benefits.

4.12 “Do Nothing” or Shoreline Retreat

The “Do Nothing” alternative or shoreline retreat is a management option that allows the shoreline to move back towards its natural state without any man-made intervention. While sometimes unpopular, shoreline retreat is often an important component of any management plan. The City will have to determine if the cost of flood and erosion protection, recreation or habitat enhancement outweighs the benefits or is an undue burden on the citizens.

The do-nothing alternative may be appropriate for those properties in a flood zone where the cost of protection far exceeds the relative cost of the structures. It may also be appropriate in undeveloped areas where the resources naturally adjust to the hydrodynamic conditions without man-made intervention.

4.13 Composite Strategies

While individual shoreline protection alternatives may alleviate erosional problems, composite strategies or a combination of alternatives may offer the best long-term comprehensive beach management. The Hampton shoreline is sediment starved; therefore the addition of sand to the littoral zone in the form of beach renourishment will help restore the beaches and provide a storm buffer. The renourished sand, however, will continue to move through and eventually out of the littoral system unless structures such as breakwaters are strategically designed to hold the sand in place. In addition, sand dunes, revetment and bulkheads can be constructed in conjunction with beach renourishment for aesthetics or to provide additional protection from flooding.

<u>Living Shorelines</u>

Living shorelines are a type of composite strategy that can provide protection while maintaining natural habitats in the shore zone. These strategies use native vegetation, sand, and rock to create a buffer between the upland and the water that provides real habitat and water quality benefits. Typical strategies include beach and dune creation and tidal marsh enhancement and creation. Oftern these systems require rock breakwaters or sills in order to maintain the new habitat. Figure 4-8 provides a typical cross-section of a living shoreline.

Composite strategies, including Living Shorelines, are the most recommended means of shoreline protection throughout the Management Plan. Beach replenishment, especially with dune enhancement and/or sill breakwater structures are effective shoreline protection along the beach fronting areas, while created wetlands may be effective along the tidal shoreline for both public and private properties.

Figure 4-7: Stabilizing structures at Salt Ponds Inlet. The north structure is a rock jetty and the south structure is a sheetpile jetty. Note the shoaling inside the inlet.

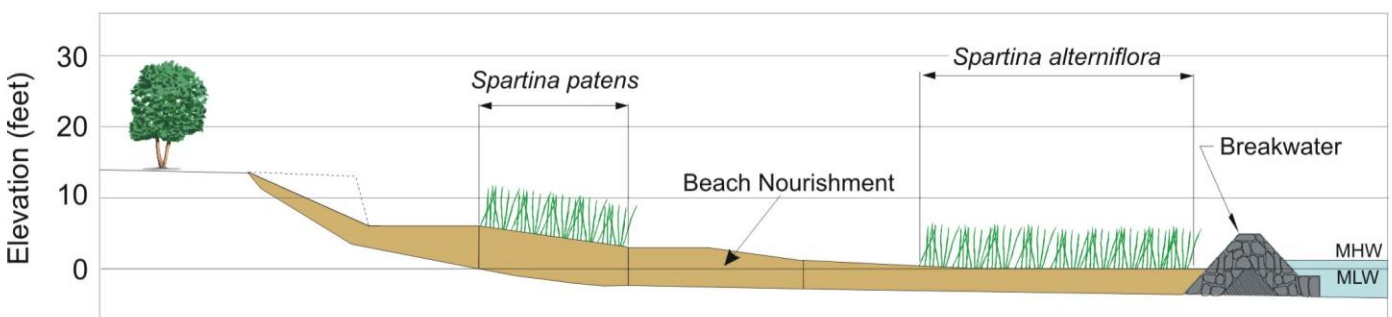


Figure 4-8: Typical living shoreline schematic depicting beach fill, low and high marsh plantings, and a protective breakwater or sill (From Hardaway and Byrne, 1999)

5.0 PHASE I - SUMMARY OF RECOMMENDATIONS

Based on initial information and model results, management alternatives were recommended for further investigation along the Hampton beachfront shoreline. Along many shoreline reaches, several alternatives or “composite strategies” have been suggested for additional evaluation in terms of empirical and numerical modeling, while a single strategy may be applicable to other reaches. It is necessary to understand that the recommendations provided for one reach, will ultimately have an impact on adjacent reaches. Therefore, it is important to evaluate the Hampton shoreline as a comprehensive unit such that the various strategies are designed and planned to enhance the characteristics of the entire beachfront, while minimizing or reducing any potential adverse impacts throughout the system.

5.1 Beach Renourishment

Beach renourishment is considered a viable shoreline protection alternative for most of the Hampton shoreline. The addition of more sand not only protects the immediate beach and infrastructure at the placement site, but also restores sediment to the littoral system. A wide berm serves as a protective buffer to storm waves and reduces the damaging impacts of wave energy. Beach renourishment, however, does not directly reduce coastal flooding above its design elevation. In addition, a wide berm provides an ancillary recreational amenity.

Beach renourishment should be further evaluated for Reach 2 (Buckroe Beach - public), Reach 3 (Malo Beach), Reach 4 (Salt Ponds), Reach 5 (White Marsh) and Reach 6 (Grandview). The southern beaches, Reaches 2, 3 and 4 (Buckroe Beach, Malo Beach and Salt Ponds), should be planned as a single linear system (if possible). Since this section of the shoreline supports the most development and infrastructure, the berm elevation and width should be designed to withstand the impacts of a 50-year storm event (if it is economically feasible.) The southernmost section of the Fort Monroe shoreline has recently been renourished. The City does not currently have any jurisdiction in Fort Monroe, however, if possible the inclusion of the Fort Monroe shoreline in a beach renourishment project with the northern beaches would significantly improve the performance of the fill. (Only the northern portion, including Dog Beach, has been modeled as part of this investigation.)

The developed section of Reach 6 (Grandview) is overly eroded and has been associated with a relatively high erosion rate. A protective seawall and revetment currently exists along this area. A renourishment project designed to withstand the impacts of a 50-year storm event would be very expensive to construct and difficult to maintain. A smaller project, however, should be evaluated to provide some additional storm protection and recreational benefits.

At this time, beach renourishment is not recommended along the southern half of Reach 8. The northern beaches are part of the Grandview Nature Preserve. In the past, the Department of Fish and Wildlife has not been supportive of beach renourishment north of Lighthouse Point due to potential impacts to the natural habitats of the Tiger beetle and Piping plover. In addition, the northerly beaches do not support any structures and have limited land access.

Periodic beach renourishment will be required to maintain the breach restoration at Back River connecting Factory Point to the Nature Preserve (northern half of Reach 8). The alternatives analysis from recent modeling (URS, 2008) suggested that sediment losses will range from about 5,600 cy/yr to 8,200 cy/year with the breakwater system in place. Renourishment may be required on a five to ten year interval depending on storm frequency and the performance of the breakwaters.

A critical factor in planning future beach renourishment projects is Salt Ponds Inlet. Currently, the inlet is on an approximate eighteen month to two-year maintenance dredging cycle to provide a safe navigation channel from Salt Ponds harbor to the Chesapeake Bay. The addition of sand to the littoral system will increase the shoaling inside the inlet unless improvements are made to the jetties at the mouth of the inlet. Also, in order to construct a linear project, easements will be required from the private sections of Malo Beach, White Marsh and Grandview.

5.2 Sand Dunes

A natural dune/bluff system currently exists along Dog Beach at Fort Monroe, Reach 3A in Malo Beach, and Reaches 7 and 8 in the Grandview Nature Preserve. The public beach at Salt Ponds currently supports a man-made dune structure with a geotube core and Reach 5 at White Marsh supports a low-lying dune that is frequently overtopped during storms.

Dune enhancement with native grass plantings should be considered along the northern section of Reach 1 (Dog Beach), Reach 3A and possibly throughout Reaches 7 and 8. Vegetation will help stabilize the existing dune structures, as well as provide habitat and an aesthetic appearance. Dune maintenance should be continued along Reach 4 in Salt Ponds. Dune construction should be considered in conjunction with a beach renourishment project at Reach 3B, and Reach 5, but without a wider and higher beach planform, the dunes will rapidly erode.

Dunes are not necessarily recommended in front of the seawalls at Buckroe Beach (Reach 2) or Grandview (Reach 6). The seawall currently serves as a protective barrier along these two reaches. In addition, due to the high public use of the beach and park at Buckroe, it would be difficult to maintain a sand dune in front of the seawall.

5.3 Shoreline Defense Strategies (Revetments and Seawalls)

Currently an array of revetment and seawalls exist along Reaches 1 through 4 and Reach 6. The seawall at Fort Monroe was recently raised to an elevation of 9.5 ft NAVD and the seawall at Buckroe is at an elevation of approximately 9.0 ft NAVD. These two structures were built with specific design considerations, while other structures were built to meet an immediate need due to erosion. Revetments and seawalls should only be constructed to engineered design criteria which are specific to each site. When possible, alternative strategies such as beach renourishment, dune construction, breakwaters and living shorelines should be investigated prior to constructing additional revetments and seawalls. Repairs to the existing seawall and revetment fronting Reach 6 would be a prudent defense strategy. When properly designed, revetment and seawalls can reduce the impacts of coastal flooding.

5.4 Process Altering Strategies (Groins, Breakwaters and Jetties)

Process altering structures include those that change wave and current properties to alter the patterns of sediment transport. Currently, the Hampton shoreline supports 24 groins, two jetties, and seven breakwaters. Additionally, the shoreline of Fort Monroe south of Dog Beach supports an additional three rock groins and five recently constructed breakwaters. The timber groins throughout Reaches 2 through 5 are past their functional design life and the jetties that stabilize Salt Ponds Inlet are also in need of improvement. The rock groin at the seawall in Grandview is a minor structure.

The existing rock groins in Reach 1 are in good condition and appear to stabilize the beach and reduce sediment losses to the south. These groins should be maintained in the future. A terminal structure or spur along the south wall at Fort Monroe has recently been constructed and should assist in perching the beach planform and further reduce sediment losses south past the seawall.

Numerical and empirical modeling procedures should be used to determine the effectiveness of the existing timber groins throughout Reaches 1 through 5 to evaluate the viability of repairing the structures. Strategically placed breakwater “T” heads on the ends of many of the groins could assist in perching the beach planform with or without a beach renourishment project. The application of various combinations of “T” head and nearshore breakwaters should be evaluated to determine their effectiveness in reducing sand loss in Reaches 1 through 4.

Fort Monroe has produced a plan for shoreline management including a large array of approximately fourteen offshore breakwaters. To date, four breakwaters and the terminal structure have been built. As of February, 2010, there was no funding to continue the construction of the additional breakwaters.

Additional nearshore breakwaters should be evaluated throughout Reaches 1 through 7. These breakwaters can be modeled and designed to protect specific areas such as the breach at Hawkins Pond in Reach 7, erosional "hot spots" such as the north end of the pubic beach at Buckroe (Reach 2), as terminal structures to maintain a renourishment project or as strategically placed structures sited throughout the study area to help anchor the shoreline. Breakwaters will reduce sediment movement throughout the littoral system. As a result, there is the potential for adverse impacts on adjacent shorelines. Breakwaters, as well as other process altering structures should only be included as a management strategy when the entire study area has been evaluated as a comprehensive system.

Breakwaters and groins are process altering structures that can stabilize beaches and reduce sediment movement. Breakwaters do not directly reduce coastal flooding.

5.5 Jetty Improvements

An important component of management planning along the Hampton shoreline includes an evaluation of Salt Ponds Inlet. If sediment is added to the system in the form of a beach renourishment project, the inlet will shoal at a faster rate requiring additional maintenance dredging. In fact, this has been occurring during the past five years. Prior to the renourishment at Salt Ponds Beach, the inlet shoaled at an approximate rate of 8,600 cy/yr (CPE et al, 1992). The current survey from January, 2011 suggests that the rate is much higher and on the order of about 12,000 to 13,000 cy/yr.

In 2005, the south jetty was replaced with a sheetpile structure and lengthened. The jetty was constructed at the same elevation as the replaced structure and has been only marginally effective at reducing the northerly transport back into the inlet. Replacement of the south jetty with a longer, rock structure has been recommended in the Salt Ponds Inlet Management Plan (CPE, 1989) and Kimley Horn, et al 2010. Additional consideration should be given to tightening the porous north jetty, mining and bypassing the proposed sand trap and constructing a spur on the north jetty.

6.0 PHASE II MODELING RESULTS

The Phase I recommendations were based on an understanding of the existing conditions along the Hampton shoreline and a knowledge of current coastal engineering practices. In order to move the management plan through the next phase, the recommendations were then modeled to determine their physical applicability to the study area. First, the dune erosion model, EDUNE was utilized to determine an appropriate beach width for effective storm protection, then the GENESIS model was run for several different scenarios of groins and breakwaters to determine which configuration would retain the proposed beach nourishment. The following section discusses the EDUNE and GENESIS model results.

6.1 Beach Renourishment (EDUNE)

The EDUNE model was used to determine a target beach width for storm protection. The general premise is that a wide beach provides a buffer which reduces wave energy before it impacts structures. Typically, the wider the sandy buffer, the less the impact of the storm wave. There is, however, an economic factor which must be considered in the design process. Depending on the local circumstances, beach renourishment can be costly. Therefore, the intent is to determine a project width that meets a desired level of protection within a reasonable budget level.

To evaluate potential project dimensions, three profiles along the Hampton shoreline were analyzed with the EDUNE model to determine the level of protection associated with different beach widths. Typical profiles for Reach 2, Reach 4 and Reach 6 were analyzed for a hypothetical storm event. A “realistic” storm scenario was modeled which assumed a storm with a surge elevation of 7.5 ft MSL and an associated 6 ft wave height with a 24 hour duration. The “typical” areas along Reaches 2 and 4 were selected for modeling because they are public beaches and will potentially dictate or at least drive the size of a constructed beach along the private areas. The revetment along Grandview was chosen to represent the shoreline north of Salt Ponds Inlet, because it is the only section of that shoreline that is developed.

It is important to note that when discussing beach renourishment, it must be understood that any sand placed in the system will have an adverse impact on shoaling at Salt Ponds Inlet. With the exception of the public beach at Buckroe and possibly Section 3A, no other area should be significantly renourished without first improving the structures at the Inlet. This study did not include any specific designs at Salt Ponds, but improvements should include sand tightening the north jetty and adding a spur near the end of the structure, lengthening and raising the south jetty, and adding a sand trap on the north side of the inlet.

6.1.1 Reach 2 (Buckroe Beach)

A typical profile was selected along the public beach at Buckroe to determine the impacts of the hypothetical storm on two different beach widths placed at an elevation of 7.5 ft to 8.0 ft MLW. Figure 6-1 (A-B) show the EDUNE results for a 125 ft beach and a 200 ft beach, respectively. The results show that even with a beach width of 125 ft, this storm event would severely impact the existing bulkhead. The bulkhead may not completely fail, but it would potentially experience structural defects. Other than flooding, additional storm damage would be limited to the structure itself since there is a lot of open space landward of the bulkhead. Based on the limited model results, the condominiums appear to be sited far enough inland to weather the impacts. The 200 ft project, however, provides enough of a buffer to significantly reduce the adverse impacts of the storm. There will be overtopping of the bulkhead, but the beach in front of the bulkhead is not lowered to the point that the waves reflect off the face of the structure.

6.1.2 Reach 4 (Salt Ponds)

A typical profile was also modeled along the public beach at Salt Ponds to determine the impacts of the hypothetical storm at that location. Salt Ponds is slightly different than Buckroe in that there is a fronting dune system that has a geotextile core. The "geotube" is not as structurally sound as the bulkhead along Buckroe, but it does provide some additional protection to the bay fronting structures. This is important because at Salt Ponds, the average housing setback to the dune face ranges between 40 ft and 60 ft. Many houses have minor retaining walls and/or small revetment between their property lines and the geotube structure. Therefore, if the geotube/dune fails, the structural integrity of the beachfront homes will be in question.

Figure 6-2 (A-B) shows the EDUNE results for a 125 ft beach and a 200 ft beach, respectively. The results suggest that even with a beach width of 125 ft, this storm event would completely destroy the dune/geotube structure and potentially cause undermining of many of the structural foundations of existing homes. The 200 ft project, however, provides enough of a buffer to reduce the storm impacts. The dune/geotube will probably still be destroyed, but it should provide sufficient buffer to protect the beachfront homes.

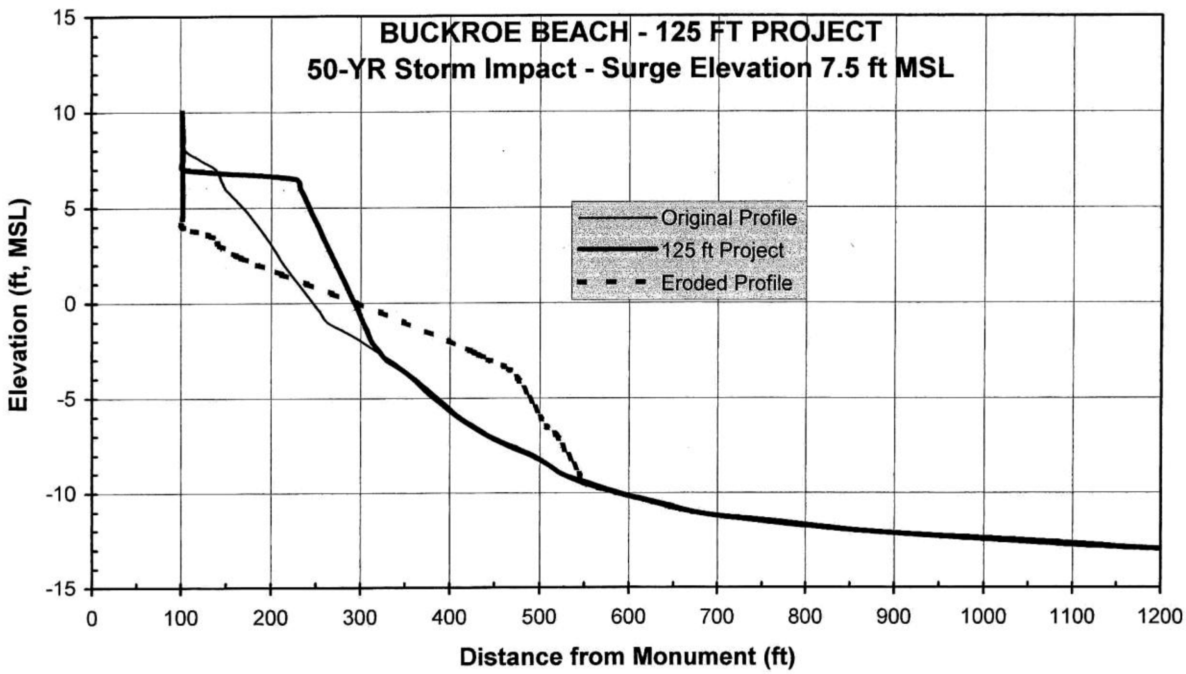


Figure 6-1A: Erosion of a 125 ft project resulting from a 50-year storm event.

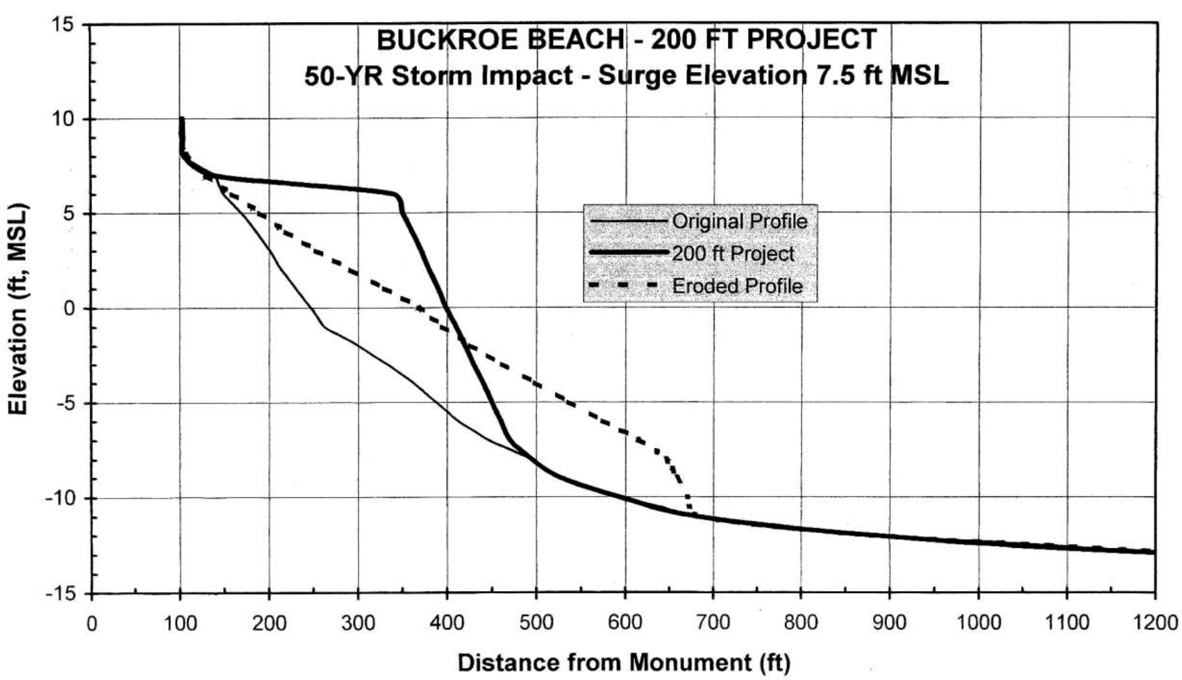


Figure 6-1B: Erosion of a 200 ft project resulting from a 50-year storm event.

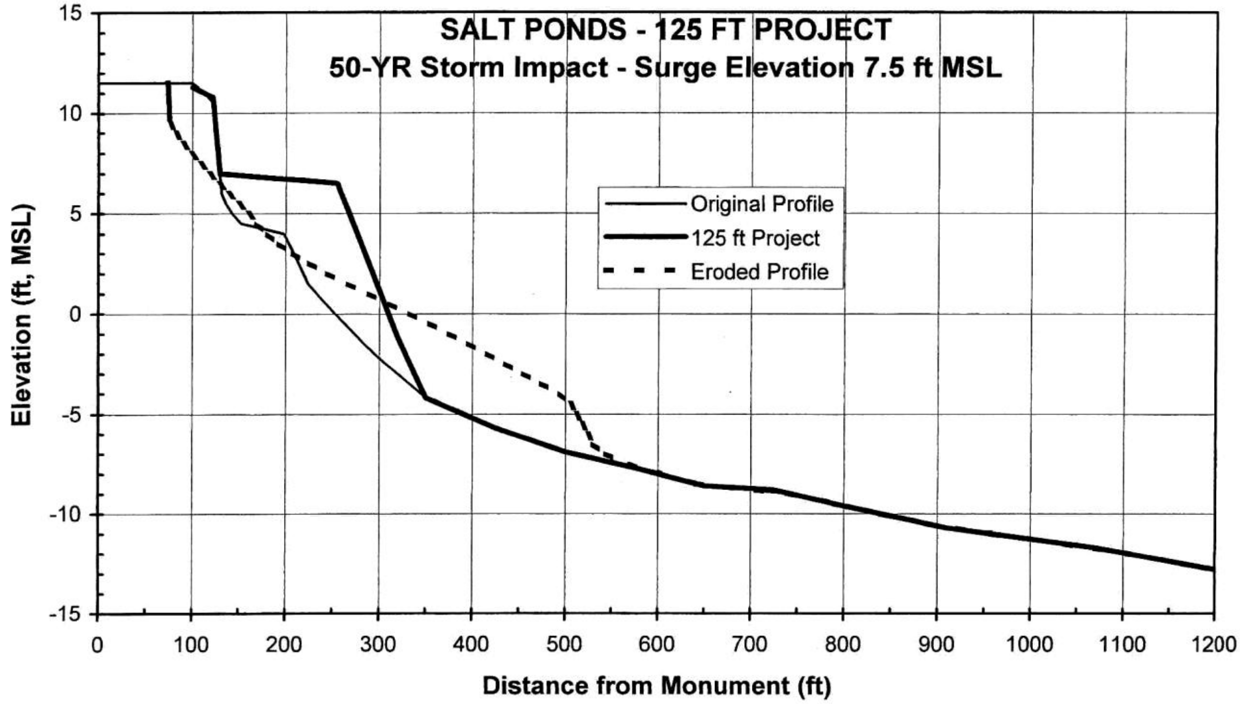


Figure 6-2A: Erosion of a125 ft project resulting from a 50-yr storm event.

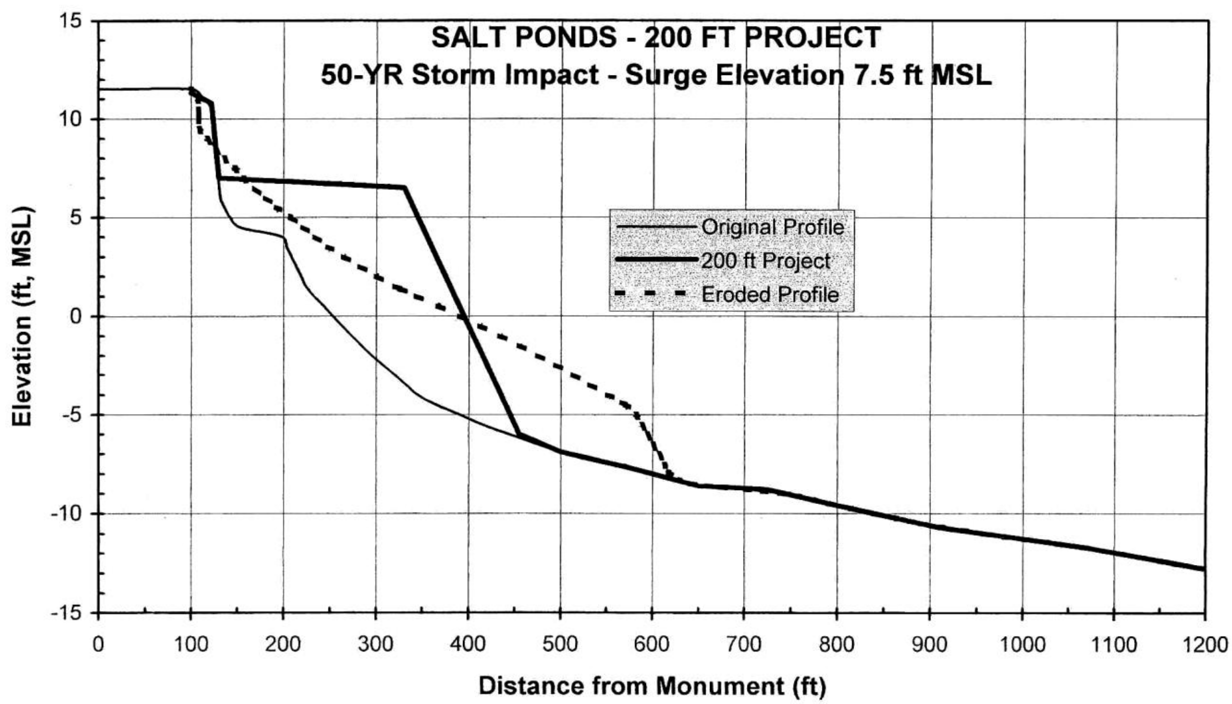


Figure 6-2B: Erosion of a 200 ft project resulting from a 50-yr storm event.

6.1.3 Reach 6 (Grandview)

A typical profile in front of the Grandview bulkhead/revetment was modeled to determine the impacts from a major storm (Figure 6-3). Since, there are no available plans or details to determine the integrity of this structure, the revetment was modeled as though it were a sand dune. As a result, this analysis was highly subjective. Additionally, due to the steep profile, highly reflective face of this structure and the fact that there is little if any beach at low tide, beach renourishment will be extremely costly along Grandview. As a result, a 100 ft beach was modeled to determine its buffering effects. A 100 ft beach typically serves as more of a recreational platform, but Figure 6-3 shows that it will provide some storm protection benefits. The eroded profile intersects the existing profile at slightly above the MSL contour. If the structure is well founded, it may not completely fail. It will likely suffer significant damage, but it may survive long enough to provide upland protection throughout the duration of the storm.

6.1.4 Recommendation for Beach Renourishment

For design purposes, it would appear prudent to construct a 200 ft beach along Reaches 2 through 4. An additional 50 ft should be added to the width for advance nourishment. This size beach is economically feasible and will significantly reduce the erosional impacts of a major storm event. In low lying areas such as Reach 3B, this size beach will not prevent flooding or overtopping, but will buffer the impact of breaking waves, thereby reducing structural damage. The model shows that the 125 ft berm provides limited protection against a large-scale storm, therefore that width should serve as the minimum design criteria for future renourishment projects.

A 100 ft berm (with 50 ft of advance nourishment) along Reaches 5 through 6 (with a taper towards Lighthouse Point) would provide a recreational platform, as well as limited storm damage benefits. It will be extremely costly to construct a wider project along the seawall at Grandview and since there are no structures to the immediate north or south, it would be difficult to justify anything wider. Constructing a 150 ft beach along the undeveloped areas provides additional recreational areas, as well as feeds sediment into a starved system, but may not be a priority in terms of storm protection.

The north end of Grandview Nature Preserve was not modeled as part of the initial study, but was modeled at a later date (URS, 2008). The modeling was not specifically for beach renourishment, but to determine the stability of a breach restoration project. The project was completed in 2010 and continued maintenance on an as needed basis is recommended.

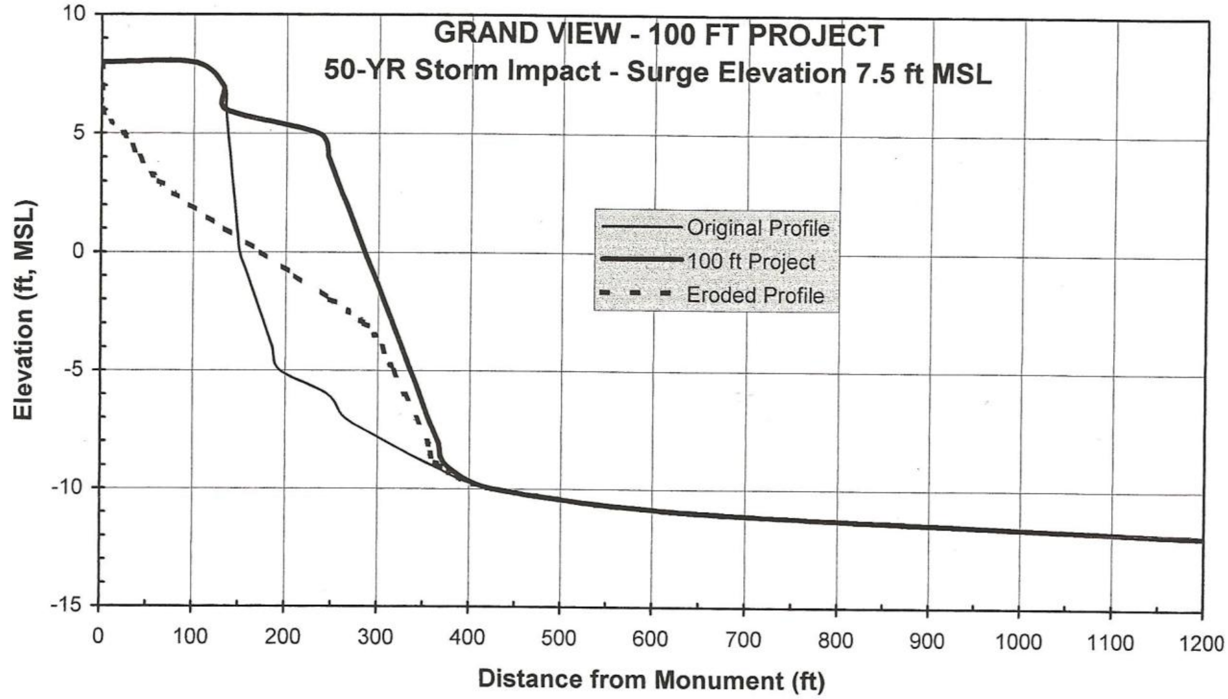


Figure 6-3A: Erosion of a 100 ft project resulting from a 50-year storm event.

6.2 Shoreline Structures (GENESIS)

GENESIS is a numerical shoreline change model that utilizes longshore transport formulae to force shore movement based on impinging wave energies. It can describe long-term trends of beach plan shape as the shoreline moves toward equilibrium under imposed wave conditions, boundary conditions, configurations of coastal structures and other input parameters. However, GENESIS works best when distinct changes occur in the shoreline such as when the shore adjusts to a project (Gravens *et al*., 1991) and generally cannot simulate a randomly fluctuating beach system in which there is no evident change in shore position.

In Phase I of this project, three baselines created for the Hampton shoreline modeling effort were calibrated and verified in GENESIS. The Buckroe Baseline extends from Fort Monroe to Salt Ponds Inlet. The Grandview Baseline extends from Salt Ponds Inlet to Lighthouse Point. The Preserve Baseline extends from Lighthouse Point to Northend Point. The model settings and parameters that were determined to provide the best shore correlation in the verification analysis of Phase I were used as the base input for the Phase II analysis. The initial shoreline for the Phase II analysis was measured from the 12 January 1998 aerial photos. This shoreline was the final measured shoreline in the verification analysis. In Phase II, GENESIS was utilized to model various configurations of structures in order to determine their impact on the shoreline. In order to denote individual runs, a three alphanumeric identifier is given for each run.

The distinct shore changes during the beach renourishment projects along Buckroe Beach provided a good data set for the calibration and verification process. In addition, the relatively coincident shoreline and offshore contours allow for confidence in the modeling results of the structural configurations at a gross scale. However, at Grandview, where the shoreline and offshore contours are skewed and more complicated, the model algorithms have difficulty accurately predicting shoreline change and sediment transport. The Preserve shoreline was not modeled in Phase II because initially no structures were recommended for that stretch of shoreline. Additionally, the calibration and verification process was difficult at this modeling scale. URS, 2008 provides GENESIS results specifically for the north end of Reach 8.

Model results from the Phase II GENESIS analysis include shoreline change, transport rate, and the average net transport per reach. The shoreline position illustrates how the beach/bay boundary will adjust when applying different structural scenarios. The consequent pattern of volumetric transport rates show changes in direction and rate of sediment movement along the beach/bay boundary. These rates are then averaged along the shore in order to determine the overall net rate of transport along the reach. The alongshore transport rates should be evaluated on the basis of patterns and relative values not as absolute transport volumes for the Hampton shoreline. Based on monitoring data, the actual transport rates maybe higher.

6.2.1 Buckroe Baseline

As shown in Figure 6-4, the Buckroe Baseline extends from Fort Monroe to Salt Ponds Inlet. The cell spacing is 100 ft. The Buckroe Baseline includes four reaches which were defined primarily due to differences in shoreline geomorphology or the physical response to the impinging hydrodynamic forces of waves and currents. These forces are difficult to model numerically when predicting how a shoreline will respond in the future.

Reach 1 is designated “Fort Monroe”, but it begins where the geomorphic boundary is defined by the small protruding rock revetment headland just south of the Buckroe Fishing Pier and extends southward about 4,600 ft to the large concrete seawall. Three, large rubble groins in Reach 1 are obstructions to littoral transport along this stretch of beach and over the past 20 years, sand transported south from the Buckroe Beach fill projects was trapped. As a result the beaches along Fort Monroe have accreted significantly. North of the small rock headland, “Buckroe Beach” which is entirely backed by a concrete seawall is designated Reach 2. It has been renourished several times over the past 20 years. It is essentially a “feeder beach” for beach sands that move primarily south into Reach 1 but also north into Reach 3. Reaches 1 - 4 support wooden groins of various sizes and in varying states of repair.

The south boundary of Reach 3 is sharply defined where the concrete seawall ends on the north boundary of Reach 2. This coincides with a change in land use and ownership from public city owned beach (Reach2) to private beach and dune (Reach 3A). Reach 3B begins where the shore protrudes slightly such that erosion has exposed the waterfront homes to wave action. Reach 3A has a wide primary dune field while Reach 3B is mostly unprotected with only several homes having bulkheaded the shore. Reach 3A has greater beach stability and storm protection capability due to the wide beach/dune system and benefits from the Buckroe Beach nourishment projects. Sand from the Buckroe Beach nourishment projects either does not enter Reach 3B or bypasses into Reach 4. The boundary between the reaches appears to be a divergent point of alongshore transport.

Reach 4 is “Salt Ponds” a public beach with private homes on the adjacent upland. It is bounded on the north by Salt Ponds Inlet. Reach 4 has received modest beach fill and the upland is protected by a large geotube dune system. Alongshore transport is to the north in this area except for a slight reversal near the inlet.

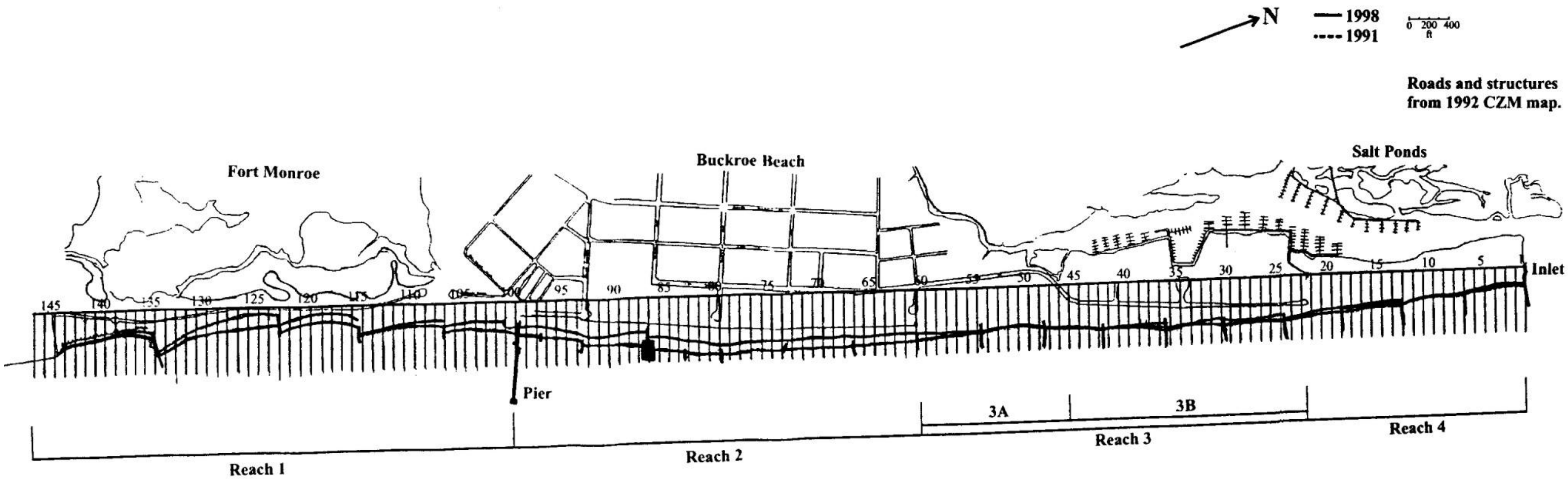


Figure 6-4: Buckroe Baseline (Reaches 1 to 4).

Some of the problems encountered in calibration and verification of the Buckroe Baseline once again occurred in the Phase II results. GENESIS has difficulty accurately modeling the closely spaced groins along the Buckroe Baseline, particularly along the public beach. At the southern end of the baseline, GENESIS over-predicts accretion along the shore near the boundary between Reach 1 and 2 and under-predicts the amount of sand accreted by the southern-most groin. In Reach 2, the model suggested more erosion than the measured data showed in the northern part of the Reach. In Reach 3A, GENESIS showed some accretion that does not exist. For the rest of the shoreline, the results are assumed to be reasonably accurate.

6.2.1.1 Beach Fill

In GENESIS, beach fills are not described by volume but rather by the total distance of shoreline advance after the fill and beach profile has been molded to an equilibrium shape by wave action (Hanson and Kraus, 1989). Beach fill can cover groins, and if the beach erodes and the groins become uncovered, GENESIS will model them as functioning.

A 250 ft beach fill was simulated along the Buckroe baseline. The width of the fill was measured from the wall along the Buckroe Public Beach shoreline (Reach 2) and from the base of the dune (or seaward side of the homes) farther north along Reaches 3 and 4. The berm is feathered at the southern end of the public beach boundary. The berm is 8 feet MLW and is assumed to contain sand material with a minimum median grain size (D50) of 0.3mm.

The GENESIS model was run first on a beach berm that extends across the entire length of Reach 2, 3, and 4. The existing groins were included and assigned a permeability coefficient that varied from almost impermeable to completely transparent depending on the location of the groin. The model was run for 10 years and 20 years, the results are shown in Figures 6-5 and 6-6, respectively. Generally, the net alongshore transport rate decreases with time (Table 6-1). The most obvious response is the large southward transport and shoreline advance into Reach 1, Fort Monroe. These results agree with empirical and monitoring data from previous Buckroe beach fills. Areas of net shore retreat or “hot spots” are evident across Reach 2 and Reach 3, particularly in Figure 6-5 as the fill equilibrates in the first 10 years. These so called hot spots occur on the shore at approximately grid cells #3, #34, #75 and # 97. To address both the beach fill loss to the south and the hot spots, structural alternatives were modeled.

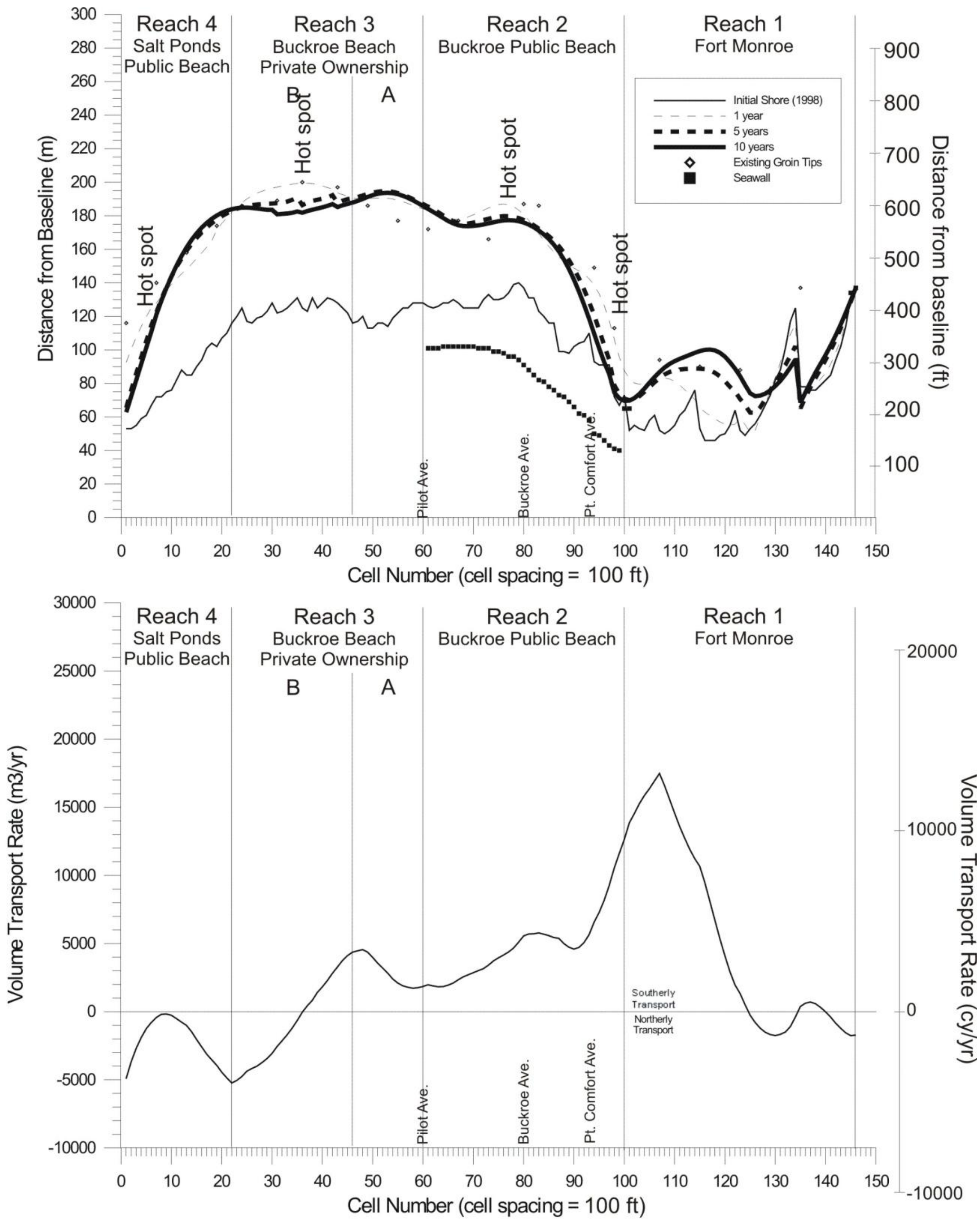
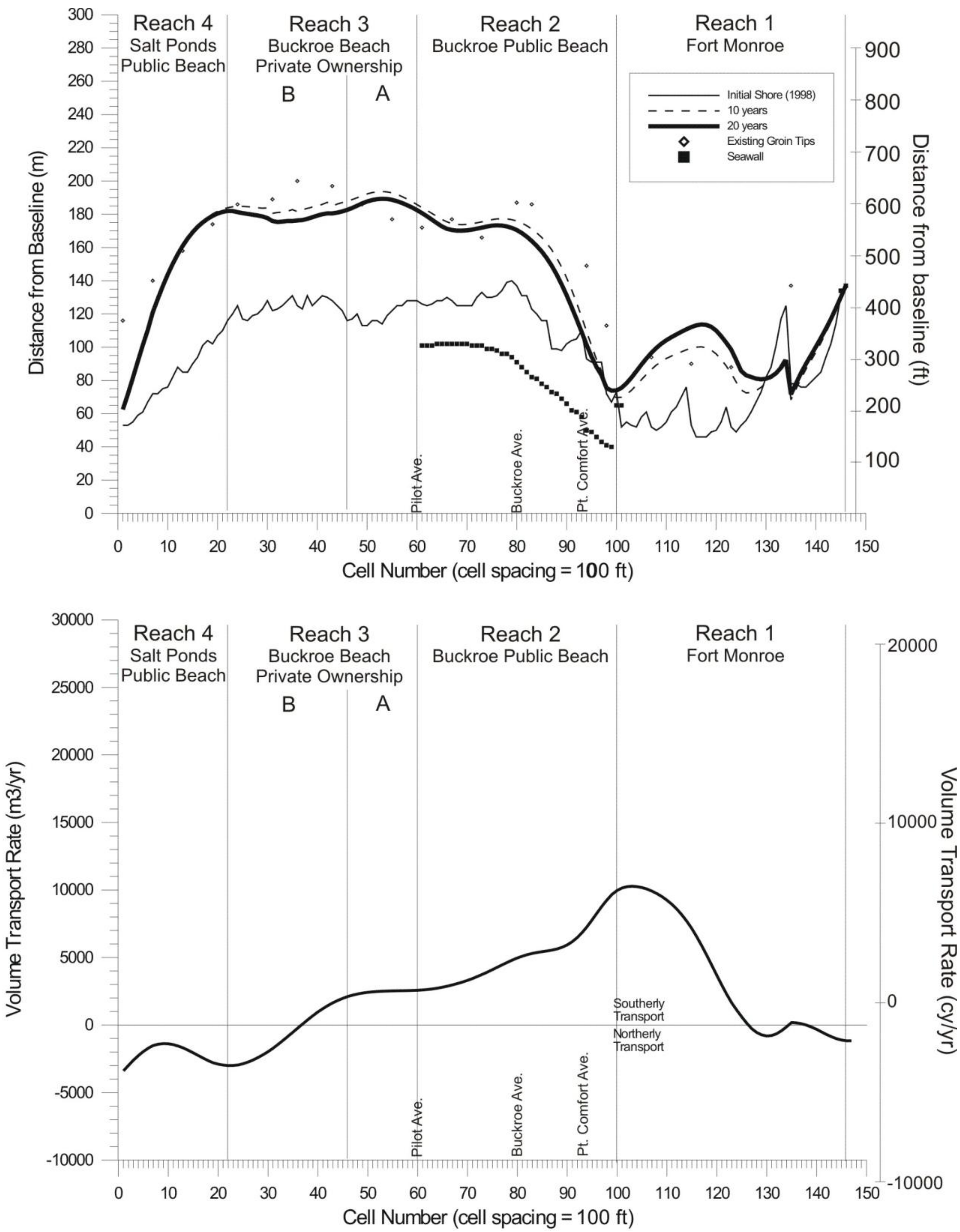


Figure 6-5: GENESIS model results for beach fill (10 years) at Buckroe (Bf1).



Beach fill only run (Bf2) for 20 years.

Figure 6-6: GENESIS model results for beach fill (20 years) at Buckroe (Bf1).

Table 6-1: Average net transport for various model runs along each reach (cy/yr).

		Reach 1	Reach 2	Reach 3A	Reach 3B	Reach 4	Gross	Net
Beach fill only (10yrs)	BF1	6,853	6,479	3,778	(863)	(2,961)	20,935	13,287
Groin repair	GE2	6,141	4,812	3,561	(1,159)	(2,066)	17,739	11,290
Hotspot 5 BW	BW8	4,020	4,662	2,512	66	(2,191)	13,451	9,070
Headland 3 BW	BW10	6,665	4,825	2,218	(418)	(1,438)	15,563	11,851
7 BW Plan	BW15	4,869	2,152	1,414	(938)	390	9,764	7,888

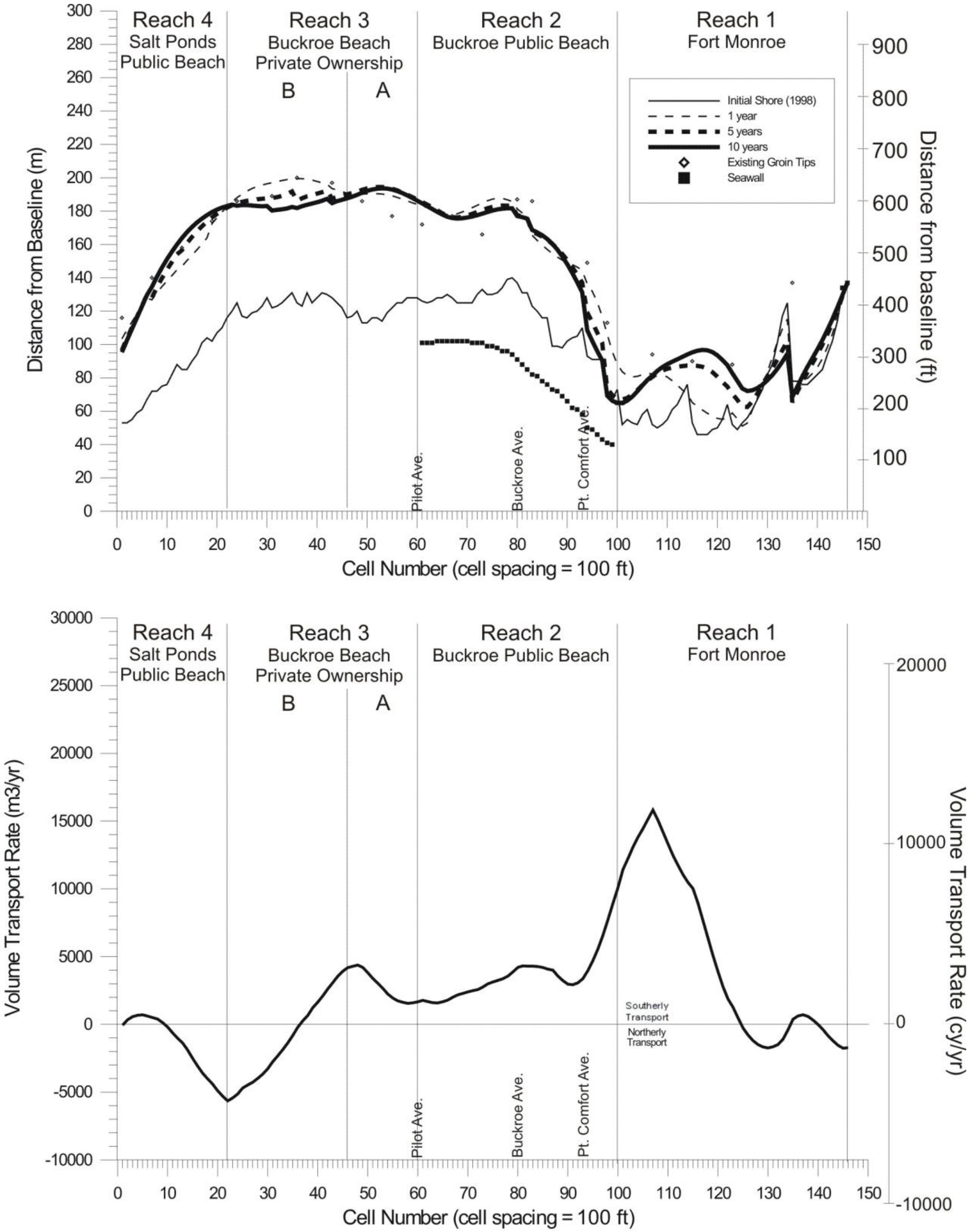
Positive transport is to the south; Negative transport is to the north.

6.2.1.2 Beach Fill with Structures

Groin Repair

Permeability values of groins and jetties were assigned to each structure to be modeled. The permeability coefficient empirically accounts for transmission of sand through and over a groin. (GENESIS automatically calculates bypassing of sand around the seaward end of groins). A permeability value of 1.0 implies a completely transparent groin whereas a value of 0.0 implies a highly impermeable groin that does not allow sand to pass through or over it (Hanson and Kraus, 1989). The initial permeabilities of the groins modeled along the Hampton shoreline were estimated from conditions described in an Espey, Huston & Associates, Inc. and Langley and McDonald report (1988). Groin and jetty permeability along Buckroe ranged from 0.2 to 1.0; these values were then confirmed in the calibration and verification process.

One of the easiest structural modifications to the shore system is to repair the existing wood groins, thereby reducing their permeability. This is modeled numerical by decreasing the permeability coefficients for the groins selected for repair. Three conditions were modeled using the verification settings and a 250 ft beach fill as the base for the model runs. In the first run, permeabilities of the groins along the Buckroe Public Beach were decreased from transparent to half transparent. In the second run, the groin repair was simulated along the rest of the baseline by decreasing the permeability coefficients. Figure 6-7 illustrates these results. The third run simulated groin repair for the entire baseline over 20 years to determine the effect of the groins if they become uncovered. *The groins did not significantly affect the hot spots or sand loss to the south (Table 6-1).*



Simulation of groin repair along the entire Buckroe baseline (GE2).

Figure 6-7: GENESIS model results for the groin repair along Buckroe (GE2).

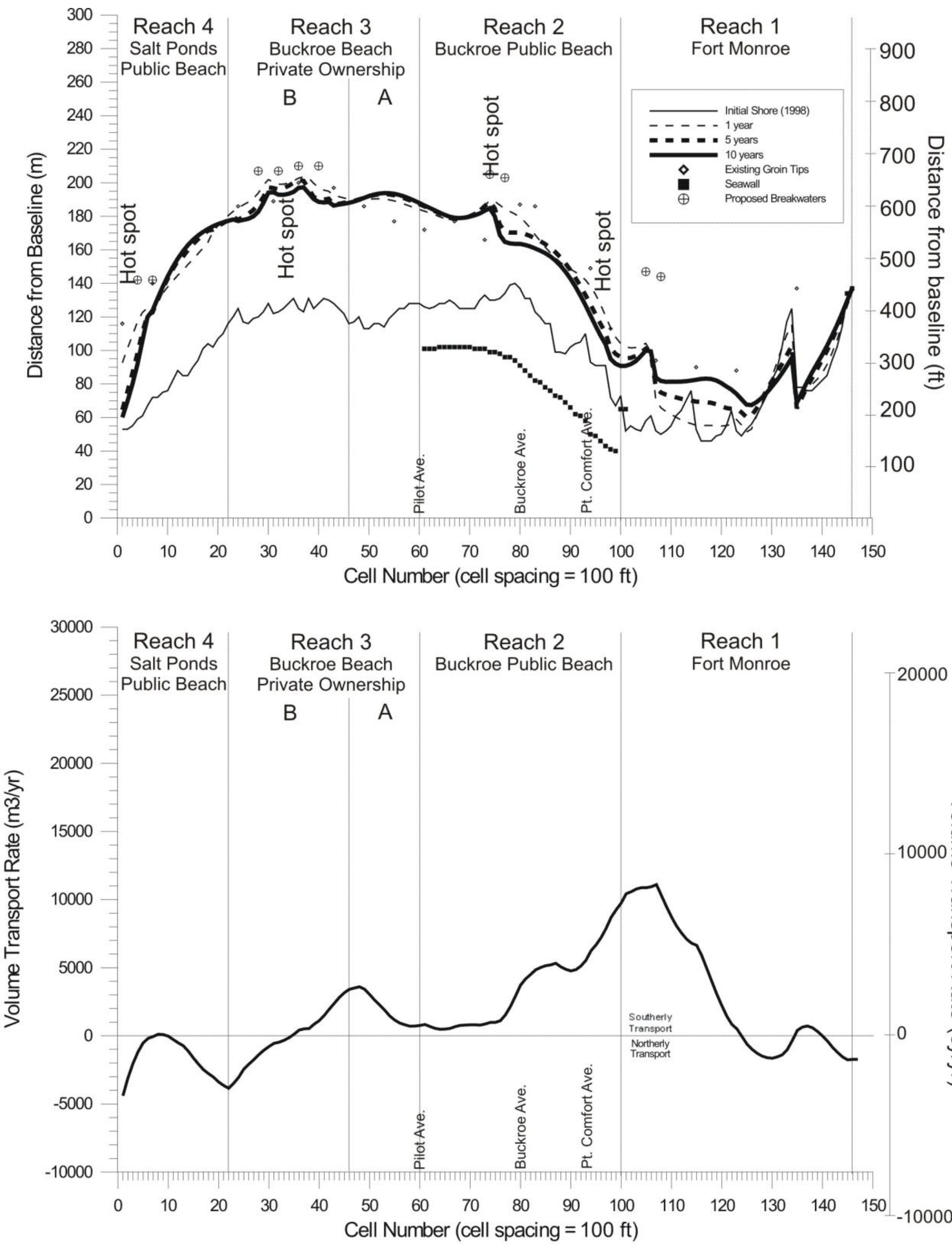
Breakwaters

Breakwaters were situated to address the areas identified as "hot spots" and to reduce sand loss to the south. The 250 ft beach berm (Figure 6-5) was used as a base for all GENESIS runs in this section. Fifteen scenarios were applied as shown in Table 6-2. All but one condition were run for 10 years. Various scenarios of breakwater number, distance offshore and permeability were run. Some performed better than others so only a selected few are shown graphically.

Figure 6-8 is a 5-breakwater scenario that placed one breakwater at "hot spot" #3, 2 breakwaters at #34 due to the length of the hot spot, one breakwater at #75 and one south of #97 to control beach movement. This scenario reduced beach loss out of Reach 2 to the south into Reach 1 and reduced loss of beach fill from Reach 3A and 3B relative to the beach fill only scenario (Table 6-1). Transport in Reach 4 was reduced slightly but hot spot #3 remained and hot spot #75 was transferred southward. Beach loss at the Reach 1/Reach 2 boundary was reduced.

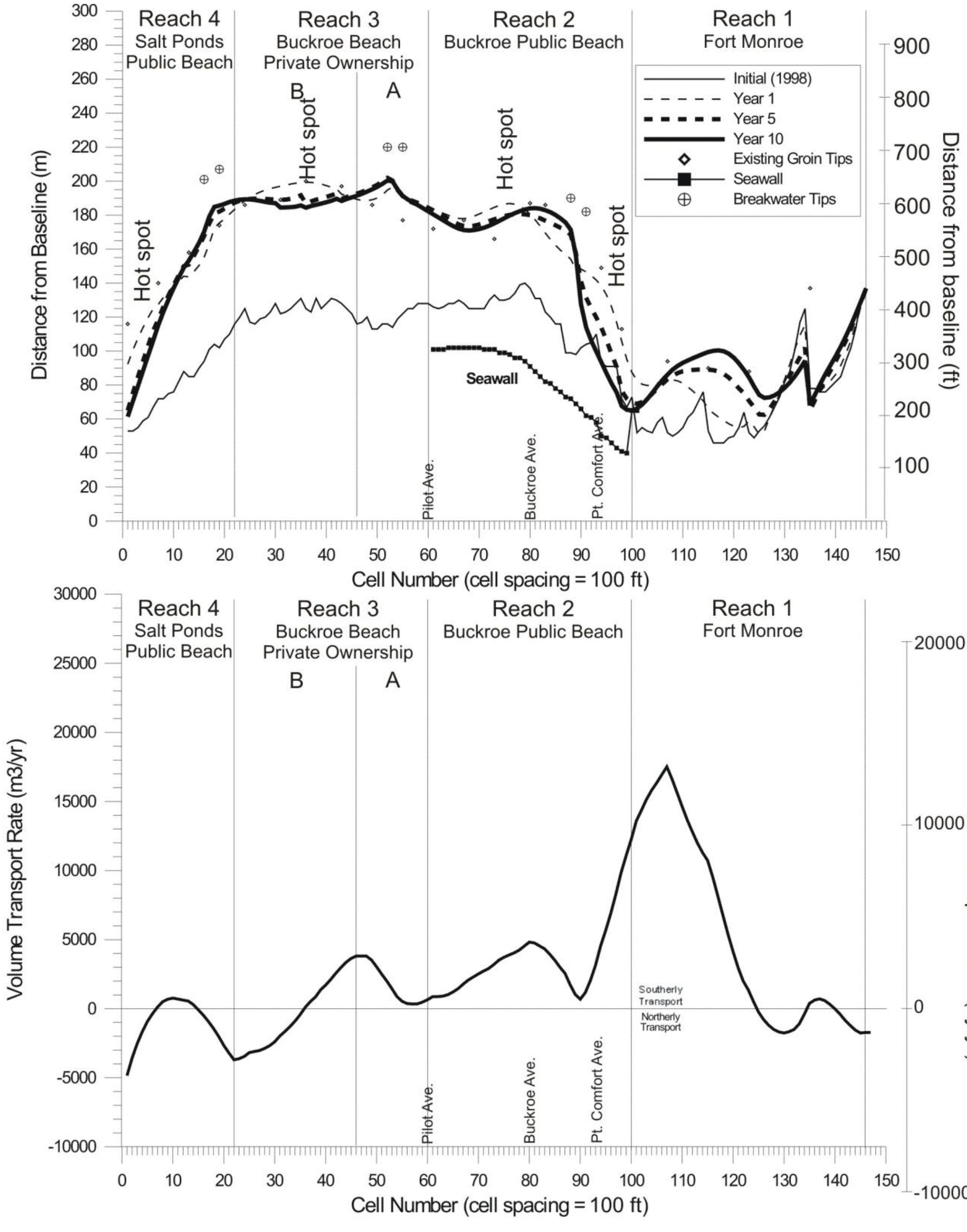
Another scenario was developed to enhance the areas between the hot spots and create broad headland features so that the hot spots would evolve into embayments. Three breakwaters were positioned in this scenario, and the results are shown in Figure 6-9. This scenario allowed more transport throughout the larger reach relative to the 5-breakwater scenario but still less that the beach fill only scenario (Table 6-1). Since only detached breakwaters can be modeled by GENESIS, it is not clear if the headland/embayment scenario is properly portrayed by GENESIS because the model was not intended for this application.

The strategy to further address the hot spots and beach loss involved placing 7 breakwaters (Figure 6-10) along the Buckroe Public Beach. This scenario further restricted beach movement and "softened" the hot spots. Southward transport was reduced, but shoreline position at the Reach 1/Reach 2 boundary was not stabilized.



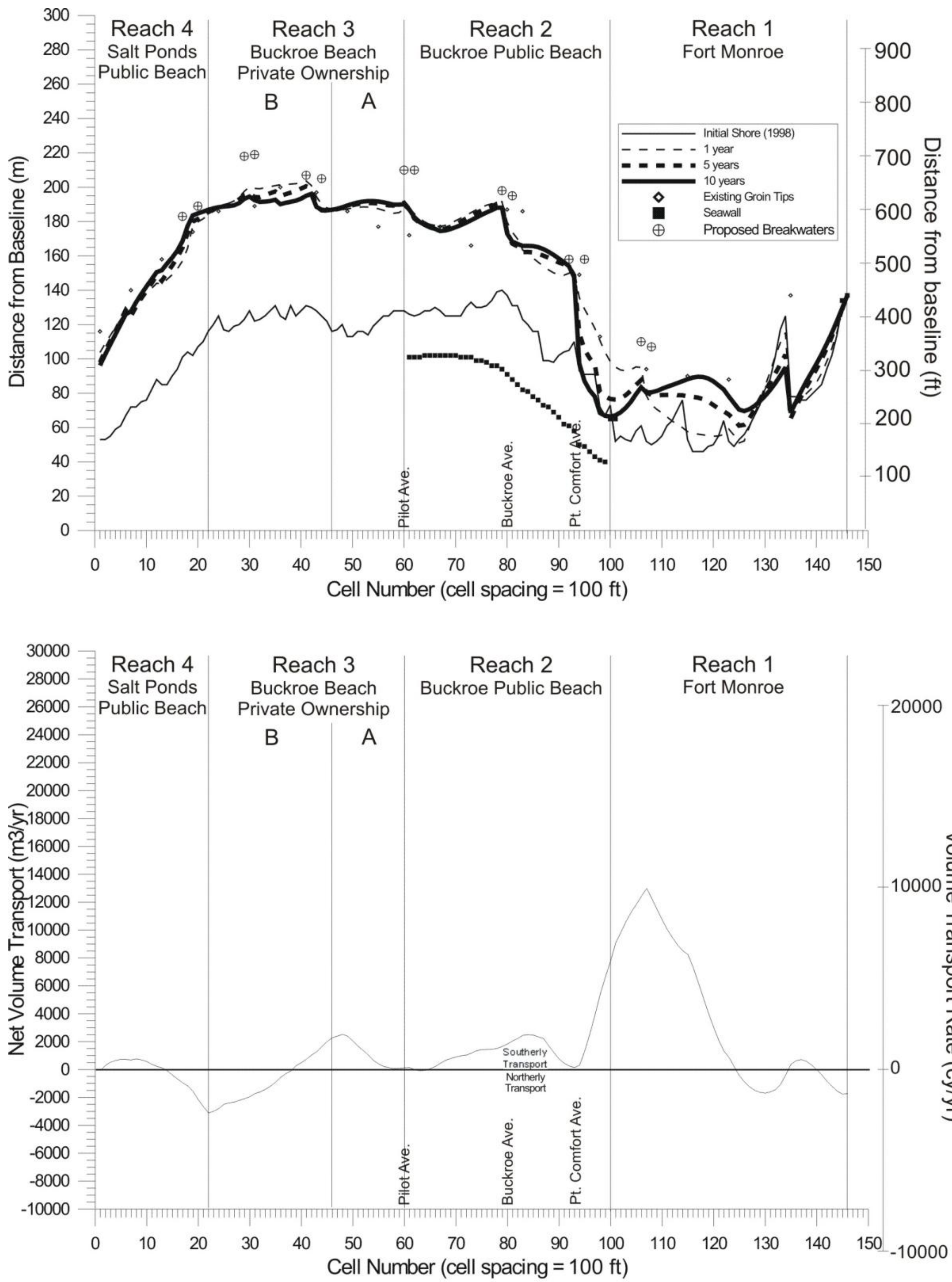
Five-breakwater scenario to address hot spots (Bw8)

Figure 6-8: GENESIS model results for the five breakwater scenario at Buckroe (Bw8).



Three-breakwater scenario to create headlands between the hot spots (Bw10)

Figure 6-9: GENESIS model results for the three breakwater scenario at Buckroe (Bw10).



Seven-breakwater scenario (Bw15)

Figure 6-10: GENESIS model results for the seven breakwater scenario at Buckroe (Bw15).

Table 6-2. Parameters modeled in various GENESIS breakwater scenarios.

No.	Run Base	Fill Width (m)	No. of BWs	BW Length (m)	BW Distance From Fill (m)	Water Depth (m)	Transmission Coefficient	Run Time (Years)	Description
BW1	BF1	76	4	90	60	1.2-1.8	0.5	10	addresses hot spots
BW2	BF1	76	4	90	60	1.2-1.8	**0.25**	10	decreased T.C.
BW3	BF1	76	4	90	**30**	**1.1-1.5**	0.5	10	moved bw in; original T.C.
BW4	BF1	76	4	90	**30**	**1.1-1.5**	**0.25**	10	moved bw in; decreased T.C.
BW5	BF1	76	4	90	**30(3);20(1)**	1.1-1.5	0.25	10	moved one bw closer to shore
BW6	BF1	76	**5**	90	**30(3);18(1);24(1)**	**1.0-1.5**	0.25	10	inserted another bw - gap 61 m between bw 2&3
BW7	BF1	76	5	**90(3);122(2)**	30(3);18(1);24(1)	1.0-1.5	0.25	10	made bw 2&3 longer and farther apart (122m gap)
BW8	BF1	76	5	90(3);122(2)	**30(3);17(1);24(1)**	1.0-1.5	0.25	10	moved one bw closer to shore
BW9	BF1	76	5	90(3);122(2)	30(3);17(1);24(1)	1.0-1.5	0.25	**20**	ran scenario for 20 years
BW10	BF1	76	3	90	46	1.5	0.25	10	bws enhance headland features
BW11	GE2	76	15	60	variable	1.5	0.5	10	t-heads on groins with decreased permeability
BW12	GE2	76	15	60	variable	1.5	0.5	10	t-heads on groins with decreased permeability
BW13	GE2	**46**	15	60	variable	1.5	0.5	10	reduced fill width with t-heads on groins
BW14	GE2	46	15	60	**~2 m from groin tip**	1.5	0.5	10	moved t-heads in until they were 2 m from the groin
BW15	GE2	76	7	90(3);60(4)	based on The Plan	1.5	0.25	10	Location of bw for the preliminary design

6.2.2 Grandview Baseline

The Grandview baseline extends from Salt Ponds Inlet northward to Lighthouse Point, and includes Reach 5, Reach 6 and Reach 7 (Figure 6-11). Cell spacing for this baseline is 200 ft. These reach designations also were developed due to the shore morphology. Reach 5 is bounded on the south side by the large stone jetty on the north side of Salt Ponds Inlet and on the north by the broken concrete around the Grandview Fishing Pier. The shoreline in Reach 5 is characterized by a continuous beach that has natural primary sand dunes along most of its length. The sand accreting against the channel jetty indicates a net movement of littoral sands to the south. Reach 6 encompasses the Grandview residential community from the Grandview Fishing Pier northward. The entire reach has been hardened with broken concrete, stacked concrete seawall and stone riprap. This area will be called Grandview Seawall, and there is no subaerial beach. Reach 7 begins at the Grandview Nature Preserve and extends from the limit of the hardened shoreline to Lighthouse Point. The shoreline is characterized by a narrow beach and eroding backshore. Lighthouse Point has and continues to act as a major headland shore feature.

The calibration and verification process from Phase I showed that, in general, agreement was good along this reach. GENESIS did tend to under-predict the erosion on the southern side of the revetment at Grandview and showed accretion on the northern side. Also, Lighthouse Point was difficult to model since little change has occurred at this Point over the study period. Some foundation rocks from the old lighthouse remain at this location. These were modeled as a diffracting groin rather than a breakwater. Because of model limitations, the predicted transport along this reach is suspect when breakwaters are placed along the shore. The interaction between the wave energy and the structures placed on complicated bathymetric contours that are deep and skewed in orientation from the shoreline cause the model to over-predict the transport that takes place along the shore.

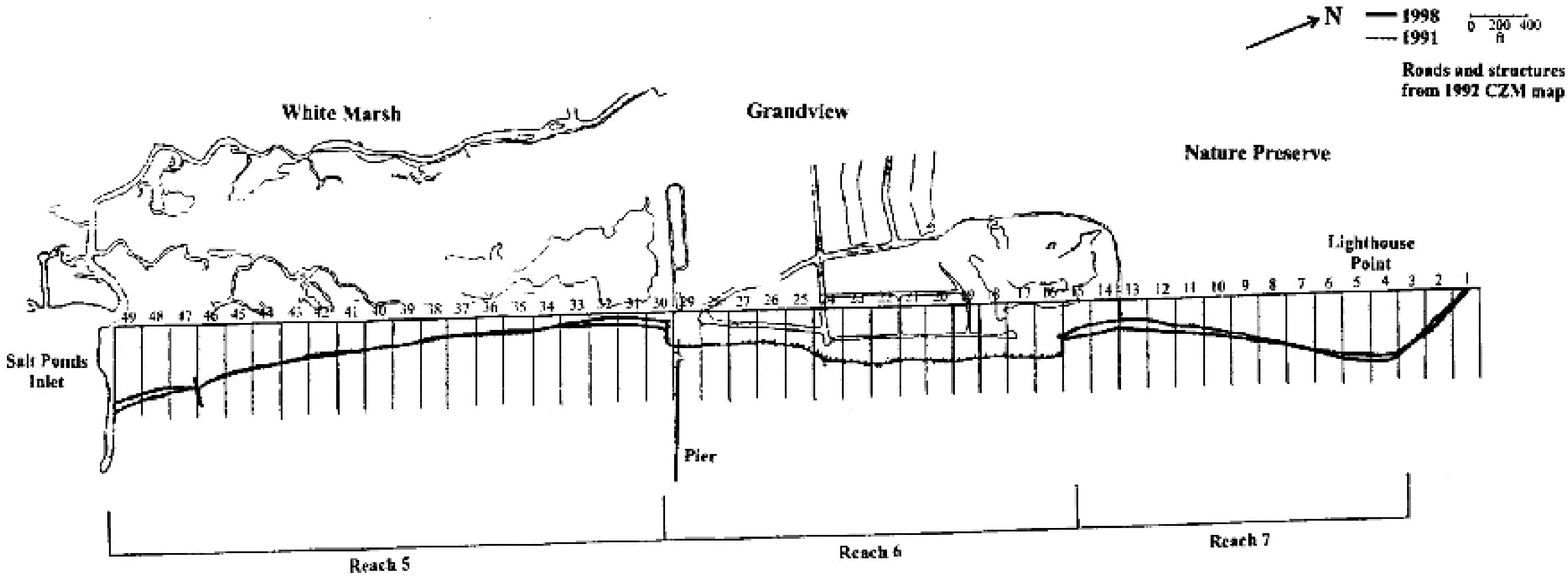


Figure 6-11: Grandview Baseline (Reaches 5 to 7.)

6.2.2.1 Beach Fill

A beach fill scenario was developed that includes a 100 ft beach berm along the entire shoreline from Salt Ponds Inlet to Lighthouse Point. The verification settings were used as a base for these runs using the 1998 measured shoreline as a starting point. The results of the 10-year run with beach fill alone (Figure 6-12) shows shoreline retreat at Lighthouse Point and consequent advance along the south half of Reach 7. The shoreline straightens across Grandview (Reach 6) and remains mostly stable across Reach 5. “Hot spots” develop at grid cells #16, #23 and #30; however, they tend cut and fill with adjacent shore cells. Hot spots #16 and #30 are critical areas at the boundary or ends of the Grandview Seawall. At cell #5, the erosion shown is a result of GENESIS’s inability to correctly model Lighthouse Point. This region has been shown to be stable over a long period of time, but the model cannot numerically simulate it.

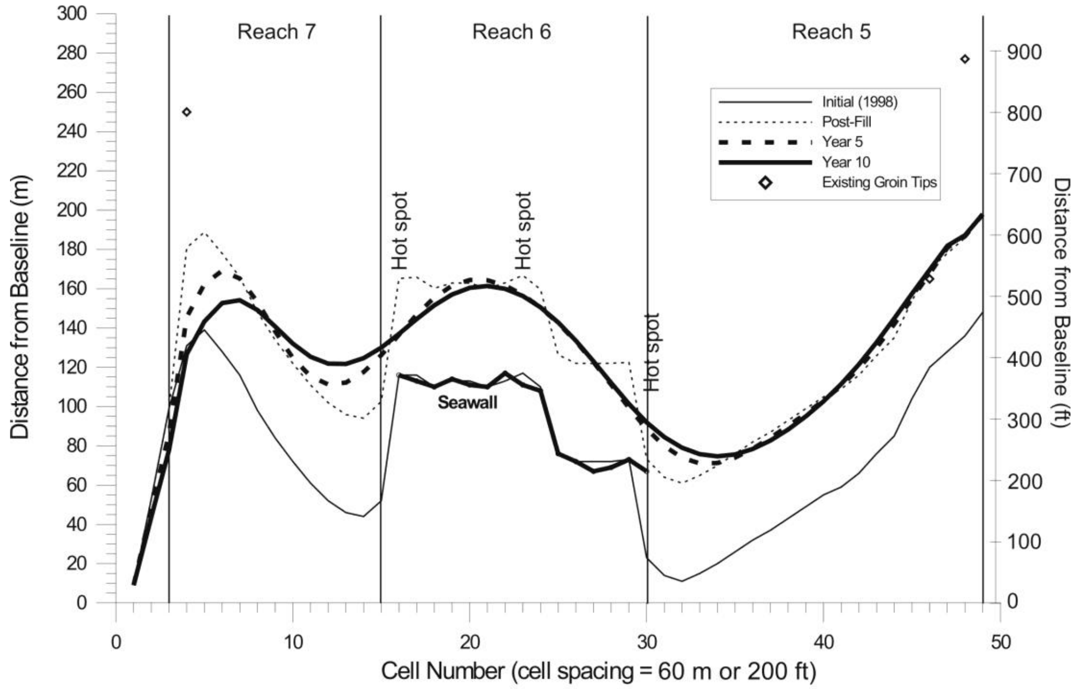
6.2.2.2 Beach Fill with Structures

<u>Groins</u>

A two-groin scenario was developed with a groin at each end of the Grandview Seawall (Figure 6-13). They were modeled as nearly impermeable, non-diffracting groins. The results show that they actually caused the shore to move closer to the seawall than the beach fill-only run.

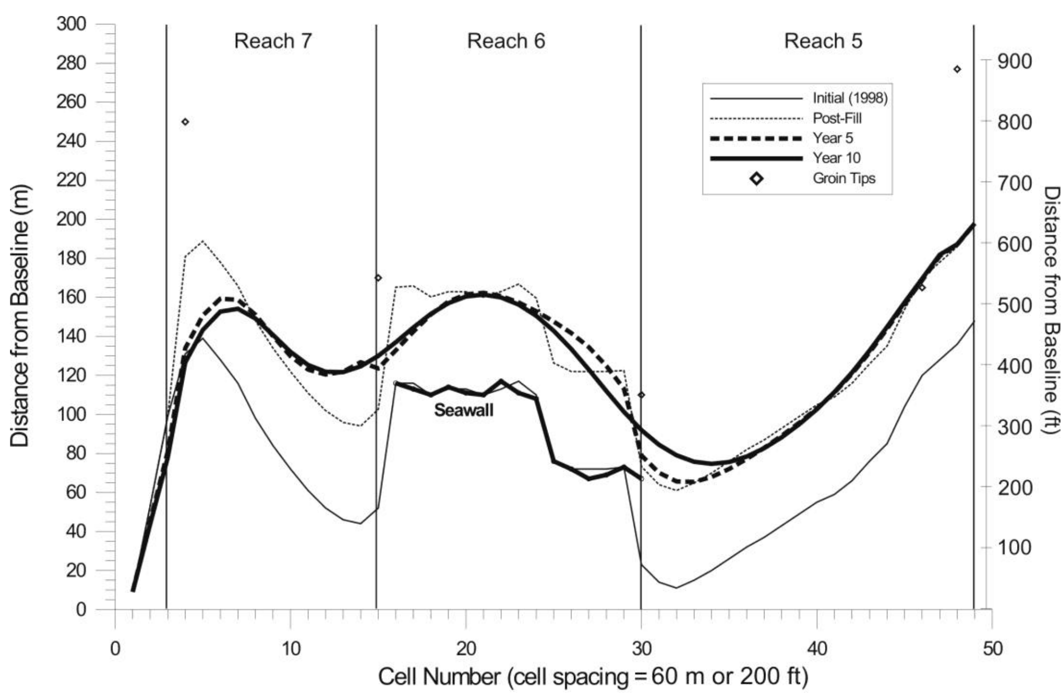
<u>Breakwaters</u>

In order to control sand movement, three individual breakwater scenarios were run with 6, 5 and 2 breakwaters, respectively (Figures 6-14, 6-15 and 6-16). The results indicate that the shoreline across Reach 5 may advance; the shore across Reach 6 would smooth out and stabilize while the beach fill place across Reach 7 would be lost from Lighthouse Point but gained along the south half of Reach 7. The 5 and 6 breakwater scenarios do a better job of maintaining beach width across and at the ends of the Grandview Seawall. These scenarios include a breakwater off the groin next to the Salt Ponds jetty. This structure helps advance and “back stack” the beach along Reach 5.



A 100 ft beach fill along the entire Grandview Baseline (Gb1)

Figure 6-12: GENESIS results for beach fill (10 years) at Grandview (Gb1).



A 100 ft beach fill along the entire Grandview Baseline with two non-diffracting, impermeable groins (Gb4).

Figure 6-13: GENESIS results for beach fill and two groins at Grandview (Gb4).

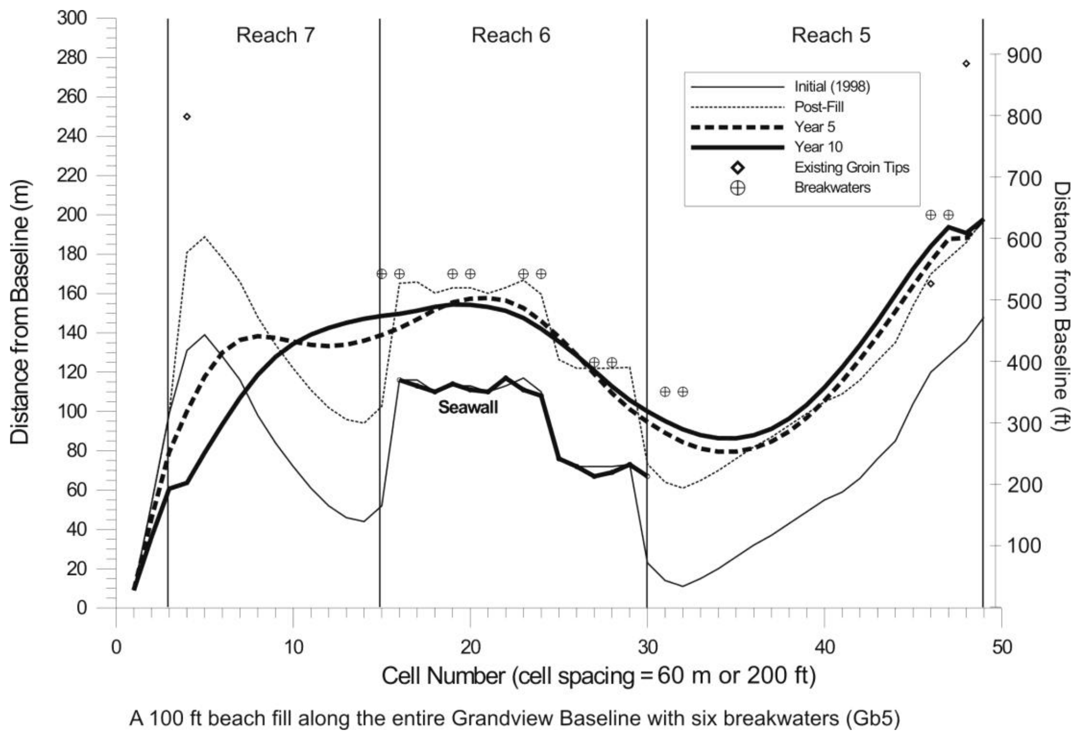


Figure 6-14: GENESIS results for fill with six breakwaters at Grandview (Gb5).

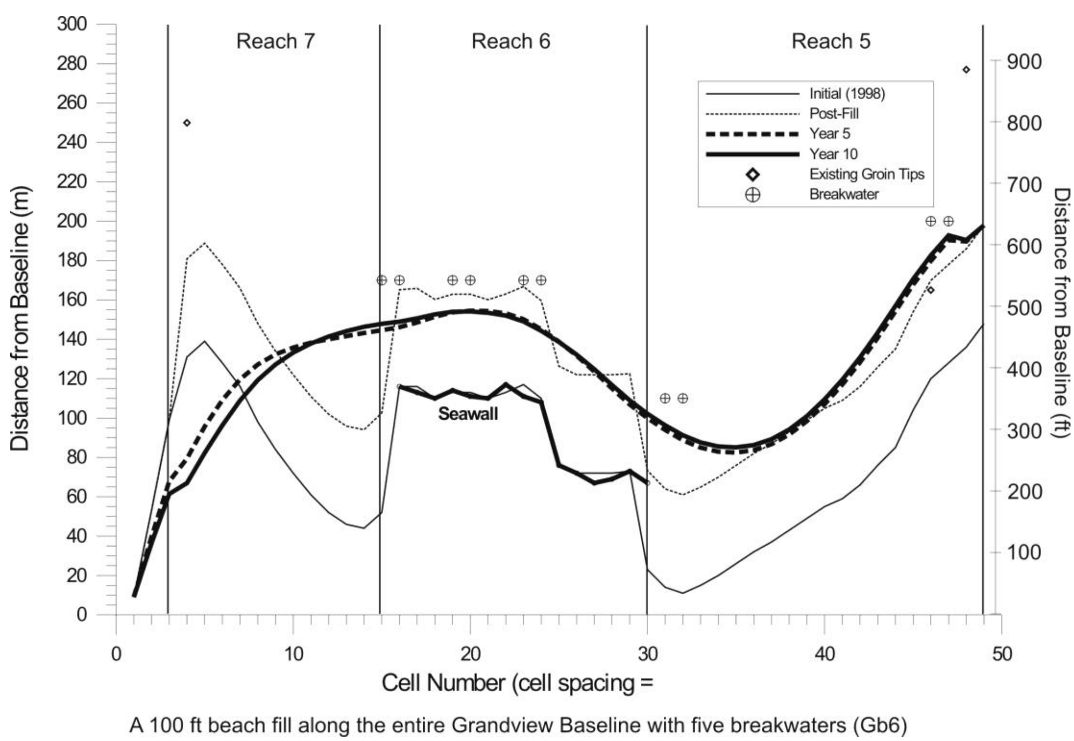


Figure 6-15: GENESIS results for fill with five breakwaters at Grandview (Gb6).

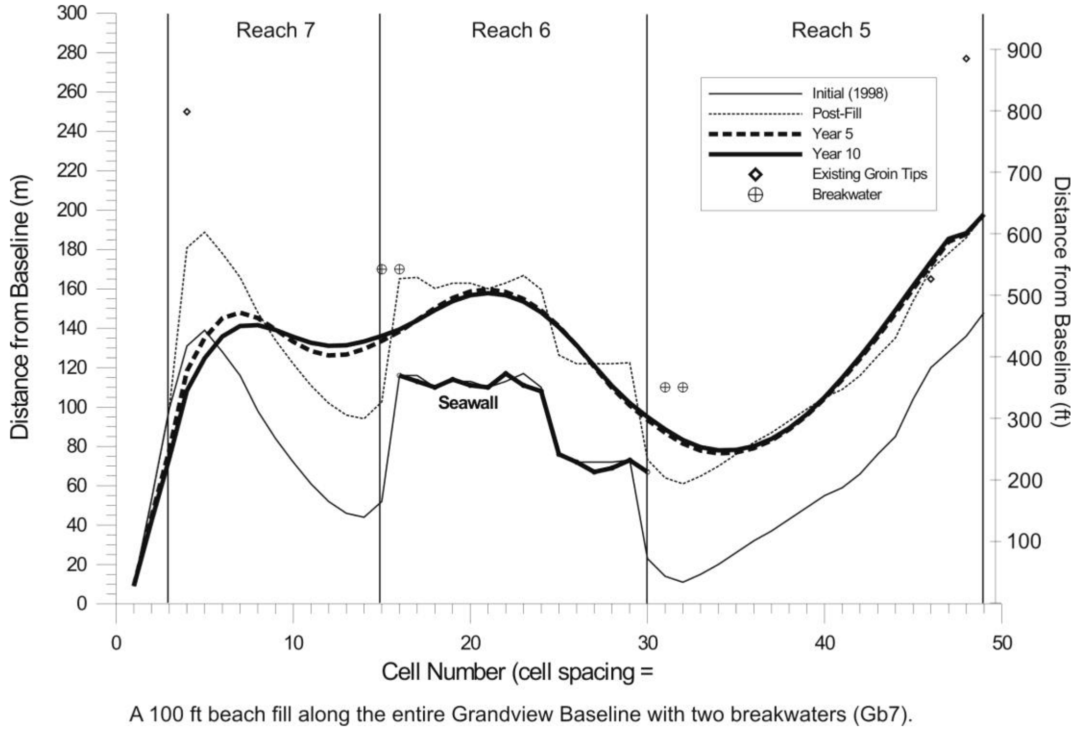


Figure 6-16: GENESIS results for fill with two breakwaters at Grandview (Gb7).

6.3 Recommendations

6.3.1 Beach Renourishment

An analysis of the EDUNE results indicated that a 200 ft beach (with an initial 50 ft of advance maintenance) would significantly buffer the impacts of a design storm with a 7.5 ft surge and 6 ft waves. The parameters suggest that this is somewhere between a 50 and 100 year storm event and would be similar to what was experienced during the Ash Wednesday storm. Coastal flooding would still occur, however direct wave impacts would be significantly decreased. A 250 ft beach would be feasible to construct along the Buckroe Baseline (Reaches 2 to 4), though it is important to understand that Reach 3 is privately owned shoreline making permitting difficult and at this time would not be eligible for state or federal funding. The public beach at Buckroe is currently eligible for federal funding and state funding (and does support a federal project) while Salt Ponds is only eligible for state funds. *The estimated cost to construct a linear beach project along Reaches 2 through 4 is $7.8 million for 780,000 cy of sand. Some of this cost can be offset through outside funds and matching grants, as available.*

Due to the fact that there are not any structures along White Marsh (Reach 5) and the Grandview Nature Preserve (Reach 7), it would not seem economically justifiable to construct a 250 ft beach along those shoreline segments. Additionally, due to the steep foreshore and overly eroded profile in Grandview (Reach 6), the cost of a 250 ft beach renourishment would be exorbitant. The construction of a 100 ft berm (with 50 ft of advance nourishment), however, would serve two purposes. First, it would add sediment to the littoral system and secondly, it would create or enhance additional recreational areas. A smaller berm along the Grandview baseline would not prevent overtopping by wave action during storms, but would provide some damage benefits to Grandview and reduce the breaching potential along White Marsh and at Hawkins Pond. *The estimated initial cost for a 150 ft berm along this section of shoreline is $5 million for about 500,000 cy of sand.*

One of the goals of the Management Plan was to establish a means or method to reduce the number of times that the offshore borrow area at Horseshoe Shoals is impacted due to dredging. GENESIS modeling was performed on several scenarios with different types of stabilization techniques to determine which were most effective. Unfortunately, these results are not specifically conclusive but do show some important trends. The qualitative analysis of the GENESIS results and scientific understanding of the hydrodynamic system along the Hampton shoreline have been predominately relied on for preliminary recommendations for stabilization.

6.3.2 Dune Construction

Dune construction and enhancement were not specifically modeled in Phase II, but it is widely accepted that dunes provide an additional barrier to storm waves. Currently low profile dunes exist along White Marsh and the Nature Preserve. Parts of Fort Monroe and Reach 3A are backed by a fairly substantial dune system, while Salt Ponds supports a man-made dune with a Geotextile core. When applicable, dune protection and enhancement with grass plantings and sand fencing are recommended. An associated cost has not been developed for this recommendation.

Reach 3B is characterized by an eroded, low profile beach backed by various types of seawalls and revetments. A dune system constructed at the time of a beach renourishment project would serve two purposes. First it would provide a "sacrificial" reservoir of sand, and secondly, it would provide both a physical and psychological barrier between the beach and private cottages. This is an important concept, especially if a public beach is constructed along this reach. A five-foot dune with a ten-foot crest would require about 6 cy/ft of sand to construct. If built at the time of the renourishment ($10/cy) and assuming additional money for grasses ($5/ft), the dune could be constructed for about $65/ft or a total cost of about $170,000. The dune should only be constructed if there is a fronting beach or it will quickly fail. If the dune were built some time after a beach renourishment with sand hauled from an upland source, then the estimate would triple.

Dune enhancement with additional plantings and slight grading could be accomplished on a case by case basis in the other reaches for about $5/ft.

6.3.3 Groin Repair

Groin repair along the Hampton shoreline was analyzed by changing the permeability coefficient in the model. Currently, the groins along the Buckroe baseline are in various state of disrepair and are considered permeable. In the model, the groins were modeled as fairly impermeable to determine the effect on sediment transport through system. The model results showed that by increasing the permeability (or repairing all the groins), sediment transport was only reduced by approximately 2000 cy/yr. This is not unexpected. The net longshore transport is highest to the south of the project area near Fort Monroe and there are several reversals in the current direction to the north towards Salt Ponds. *Groins do not have any major impact on onshore/offshore processes; therefore they do not provide significant protection during storm events. At this time, there is no recommendation for groin repair along Buckroe and Salt Ponds (Reaches 2 through 4). A scenario using two groins was modeled for Grandview. Similar to Buckroe, the groins did little to stabilize the beach renourishment project. As a result, there are no recommendations for groin construction at Grandview.*

The ends of the existing groins should be clearly marked for safety purposes.

6.3.4 Breakwaters

Several breakwater scenarios were modeled to determine the best configuration to retain the beach fill along both the Buckroe and the Grandview baselines. The overall reduction in volumetric losses is less than expected. For instance, along Reaches 1 through 4, the net transport for the "unstabilized" beach fill over a 10-year period is about 13,287 cy/yr. The modeled scenarios utilizing 3, 5 and 7 breakwaters reduces the net transport to 11,851 cy/yr, 9,070 cy/yr and 7,888 cy/yr, respectively. It is important to note, that much of the erosion along the Hampton shoreline is caused by storms. Breakwaters will not only reduce the sediment transport during "typical" conditions, but will also reduce wave energy, thereby lessening the impacts due to storms.

At first, it would appear that adding breakwaters to the system would not necessarily justify the added cost. The hypothetical reduction in net transport with the addition of 5 breakwaters would only be about 4,217 cy/yr or 42,170 cy over a ten-year period. At an estimated cost of $10/cy for renourishment, the reduction in transport would result in a benefit of about $421,700 during the first 10 years. The estimated cost of 5 breakwaters, however, is on the order of $2.0 million (not including sand costs for tombolos). At first glance, this number is somewhat misleading. Over a 50-year project life, the cost of sand will continue to increase, while the maintenance costs on the breakwaters is minimal or flat. This analysis also only justifies typical conditions along the shoreline; it does not include the added direct benefits of wave energy reduction during storms. Recent survey results show that along Buckroe, the renourishment project along the north end of the project (a former hotspot) eroded at about half the rate as the unprotected areas to the north. A correctly designed and installed breakwater system should hold a beach to the design planform. Sand may only need to be replenished after storms.

The recommendation for the Buckroe Baseline is to construct 6 strategically placed breakwaters along Reaches 1 through 4 and a terminal breakwater at Dog Beach in Fort Monroe. Figure 6-17 A-B provides the approximate location and cross-sectional dimensions of the proposed breakwaters. In the figures, those structures that were proposed and have been constructed to date, have been darkened, while the proposed structures that have not been built have not been filled in. Table 6-3 provides the estimated costs for renourishment, dune and breakwater construction for each of the reaches.

The model results for breakwaters along White Marsh and Grandview were inconclusive and the sand transport rates were not reliable. Various test runs showed that the more breakwaters along the shoreline, the higher the sediment transport rates. In reality, this should not be the case. As demonstrated along other local shoreline reaches, breakwaters decrease wave energy and reduce sediment movement through the area. To minimize renourishment losses, two breakwaters are proposed along White Marsh and three breakwaters have been proposed along the Grandview seawall. (The northernmost breakwater should be sited to offer protection to Hawkins Pond as well as anchor the renourishment project at Grandview.) Due to the deep water along the seawall, breakwater construction is extremely expensive. The total estimated cost to construct the five breakwaters (not including tombolos) is on the order of $2.66 million. Although not modeled, it is suggested that a breakwater structure at Lighthouse Point would help anchor the shoreline providing benefit to both the Nature Preserve and Grandview. An estimated budget for that structure is $675,000. Figures 6-16 C-D show recommended improvements for White Marsh and Grandview.

6.4 Salt Ponds Inlet Improvements

Salt Ponds Inlet requires structural improvements to reduce shoaling. It is imperative that improvements are made prior to beach renourishment activities in Reaches 3, 4, 5 and 6. Sediment added to the system in any of those reaches has the potential to increase shoaling in the Inlet. Currently, the navigational channel requires dredging every eighteen months to two years. The volume of material removed during each dredging cycle is currently on the order of 20,000 cy, which corresponds to a rate of about 12,000 to 13,000 cy/yr. About 40 percent of the material shoals along the north side of the channel, while approximately 60 percent has settled on the south side. An addition of sand to the system through beach renourishment will increase the sediment movement in the vicinity of the Inlet which could potentially create hazardous navigation conditions.

Specific designs for Salt Ponds Inlet were beyond the scope of this study, however, Inlet Management Plans (CPE et al, 1992 and Kimley, Horn, et al 2010) were completed that recommended various improvements. Improvements were made in 2005, but they have not reduced shoaling in the inlet. To date, final management decisions have not been made regarding structural improvements, however, a budget on the order of $2.5 million is a realistic estimate.

6.5 Factory Point Beach Restoration

Factory Point improvements were not modeled as part of the original management plan studies conducted in 1999 and 2002. URS, 2008 provides details of the modeling conducted to develop engineering designs for the restoration project. The designs were developed further with additional input from VIMS. Figure 6-17E provides the 1992 shoreline condition superimposed with the final project constructed in 2010. Approximately 145,000 cy of sand was dredged from the nearshore region and shaped into a beach with a dune, breakwaters and tombolos in order to connect Factory Island to the mainland. Navigation channels were also improved as part of the project. The estimated cost for the breakwaters and beach restoration was $2.45 million.

Table 6-3: Estimated construction costs of proposed shoreline improvements along the Hampton Shoreline (2011).

Shoreline	Reach	Renourishment Volume (cy)	Renourishment Cost ($10/cy)	Number of Breakwaters	Breakwater Crest Length (ft)	Breakwater Cost ($100/ton)	Tombolo Fill (cy)	Tombolo Fill Cost ($25/cy)
1	Fort Monroe/TS	0	$0	I	150	$240,000	2,000	$50,000
2	Buckroe (Public)	275,000	$2,750,000	II	250	$400,000	2,000	$50,000
				III	250	$400,000	2,000	$50,000
				IV	250	$400,000	2,000	$50,000
3A	Malo Private (S)	110,000	$1,110,000					
3B	Malo Private (N)	225,000	$1,575,000	V	250	$400,000	2,000	$50,000
				VI	250	$400,000	2,000	$50,000
4	Salt Ponds	170,000	$1,700,000	VII	250	$400,000	2,000	$50,000
				Jetty Improvements – Budget estimate not reflective of design - $2,500,000				
5	White Marsh	200,000	$2,000,000	VII	200	$320,000	2,000	$50,000
				IX	250	$462,500	3,500	$87,500
6	Grandview	250,000	$2,500,000	X	250	$625,000	5,000	$125,000
				XI	250	$625,000	5,000	$125,000
				XII	250	$625,000	5,000	$125,000
7	Nature Preserve - S	50,000	$500,000	Lighthouse Point Breakwater – Budget estimate not reflective of design - $675,000				
8	Nature Preserve - N	145,000	1,450,000	5	varies	$1,000,000	Part of Renourishment Cost	

Implementation of Entire Plan	Beach Renourishment (Proposed)	$13,585,000
(Does not include main-tenance renourishment	Constructed as of 2011	$ 5,900,000
or federal cost sharing	Breakwaters and Tombolos (Proposed)	$ 7,835,000
at Buckroe)	Constructed as of 2011	$ 2,350,000 (Breakwaters II, III, IV & Breach Repair)
	Jetty Improvements – Proposed Estimate	$ 2,500,000

Note: Tombolo fill estimates are generic and are provided as an additional expense to allow construction access to the breakwater site, as well as to create more of an equilibrium shoreline. The additional tombolo fill may or may not be required depending on method of construction and if a renourishment project is constructed simultaneously with the breakwater. The “constructed as of 2011” costs reflect the projected costs from the table and not the actual construction costs. The two values, however, are within approximately 10 %.

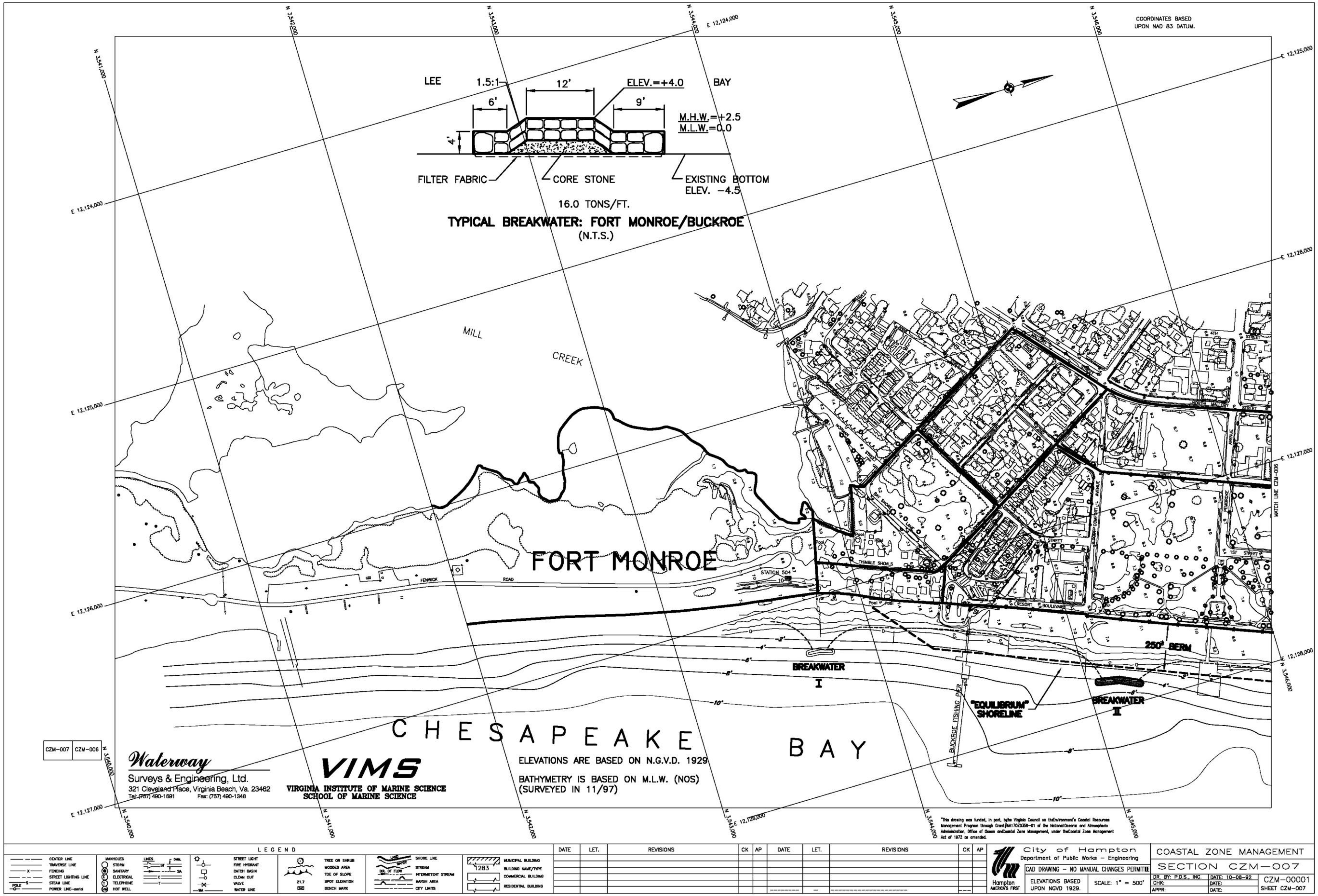


Figure 6-17 A: Recommended shoreline improvements along Dog Beach, Thimble Shoals Court and Southern Buckroe Beach.

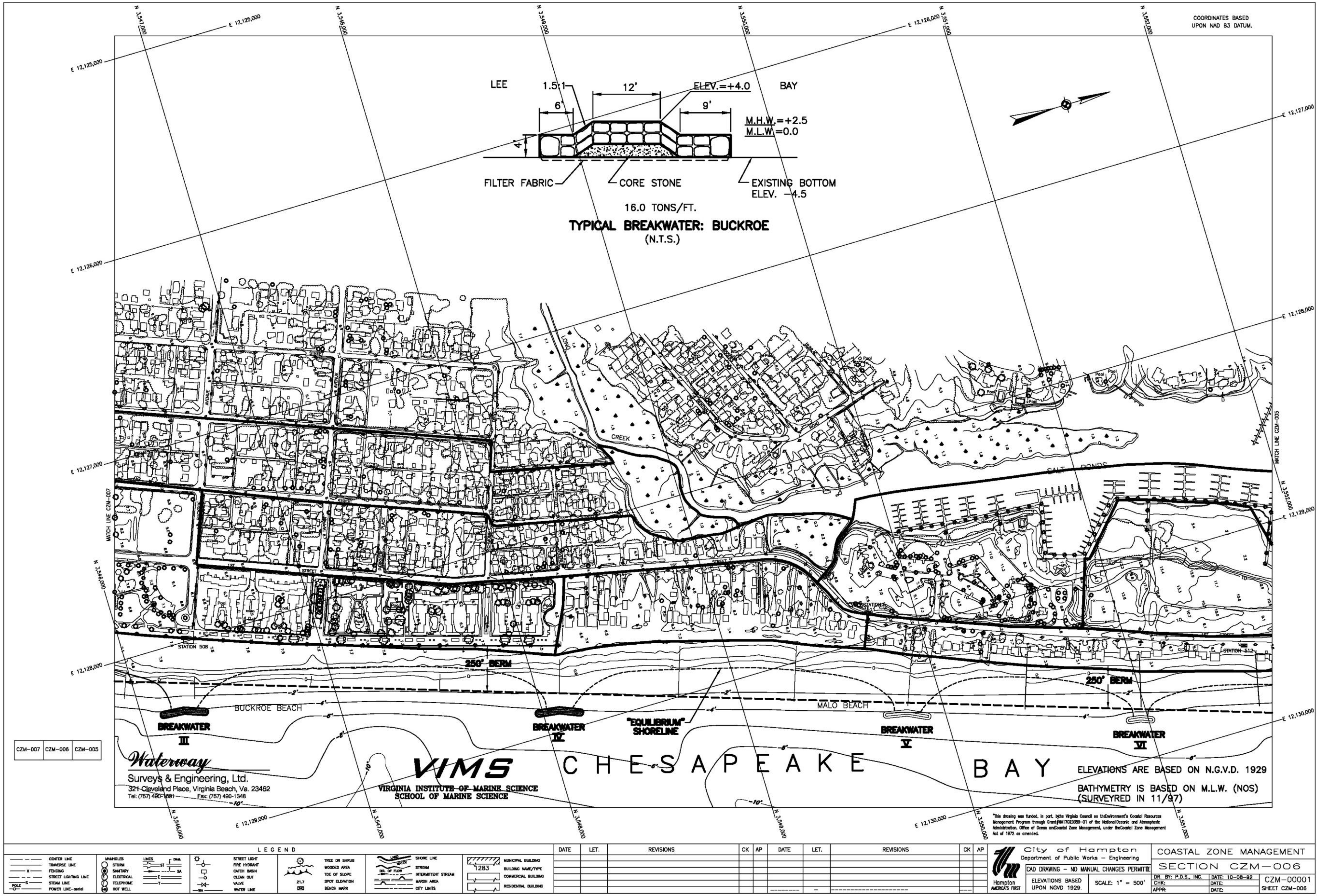


Figure 6-17 B: Recommended shoreline improvements along Buckroe Beach and Malo Beach.

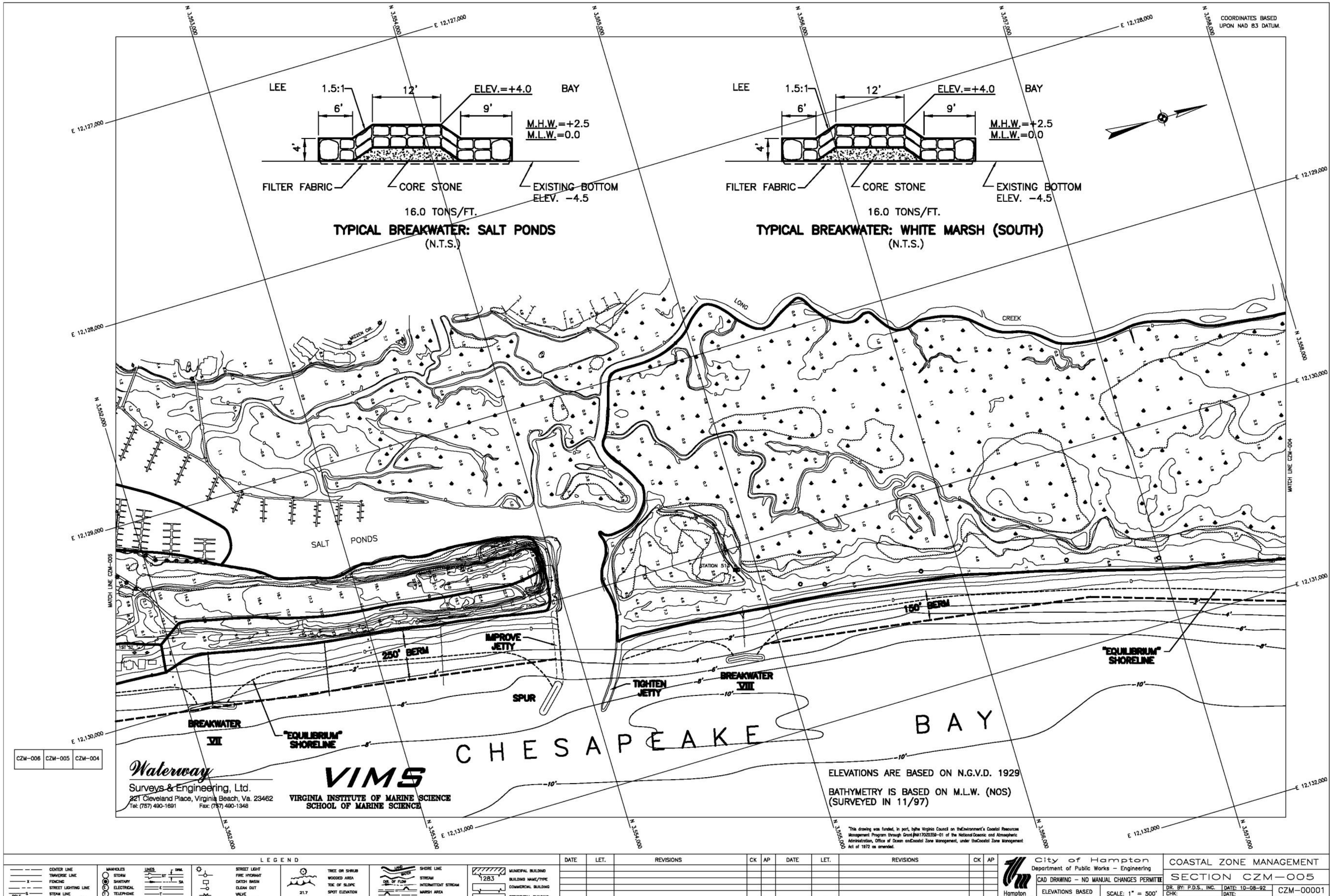


Figure 6-17C: Recommended shoreline improvements along Salt Ponds Beach and White Marsh.

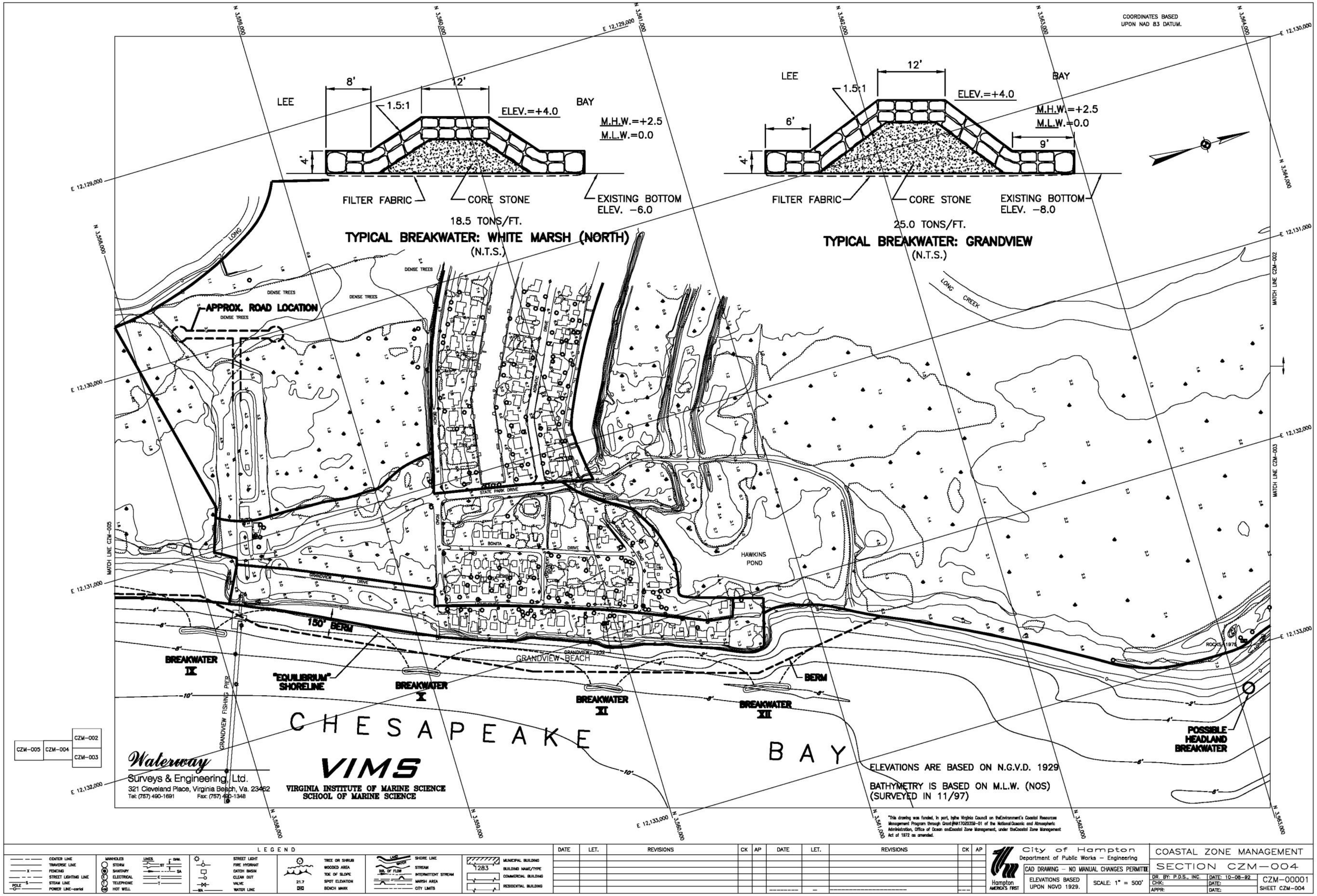


Figure 6-17 D: Recommended shoreline improvements along northern White Marsh to Lighthouse Point.

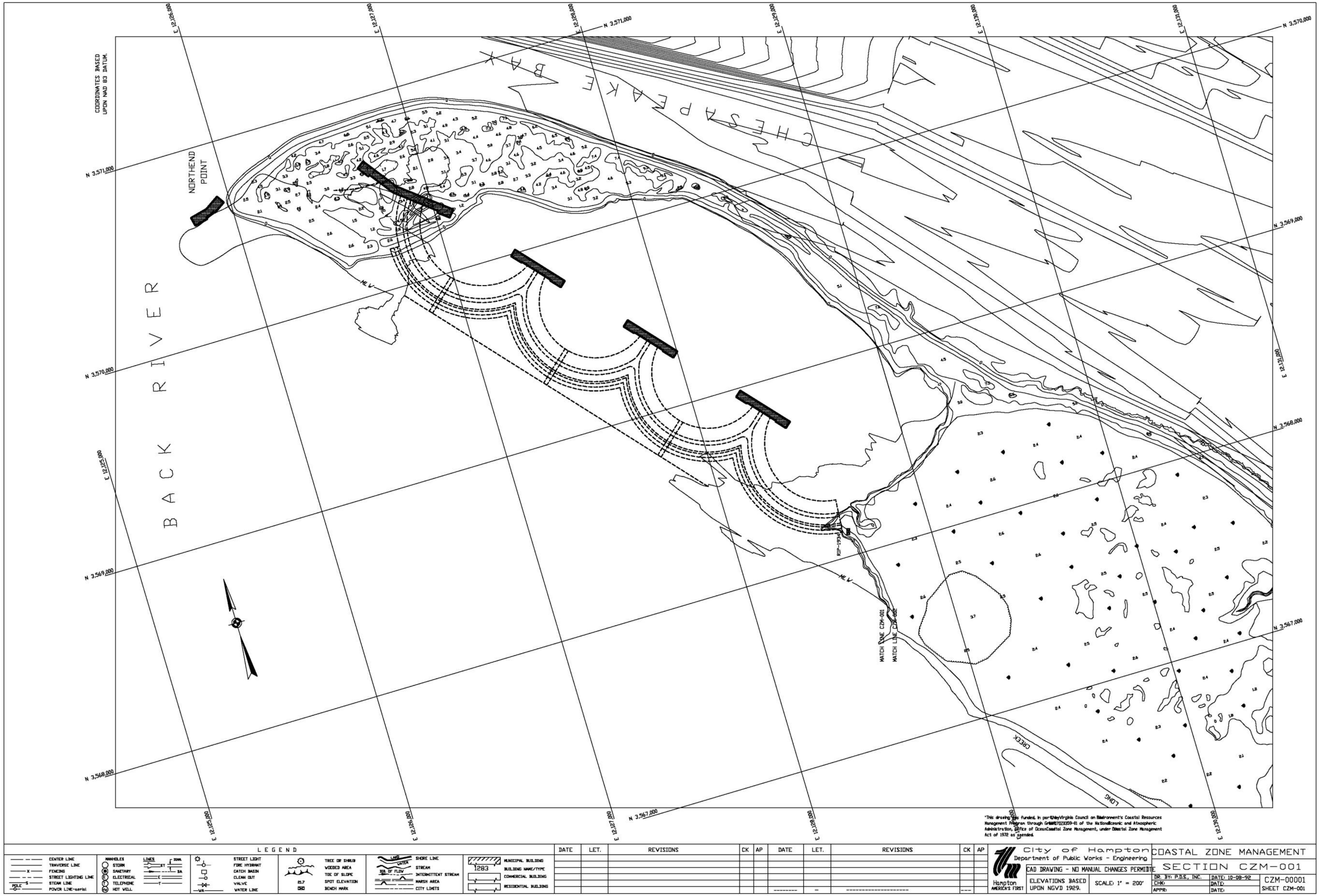


Figure 6-17 E: Recommended shoreline improvements along Reach 8 – Grandview Nature Preserve - north.

7.0 THE VALUE OF THE HAMPTON SHORELINE

The "value" of beaches is very difficult to quantify due to the various types of public and private shoreline located throughout the City. Value can be estimated in terms of "benefits" and include items such as storm damage reduction to dwellings and infrastructure, an increase in property value due to "waterfront" status, or even as a direct source of revenue from tourism or other related commercial venues. Other values, however, are more difficult to quantify because they are associated with quality of life issues and aesthetics.

A resort area, such as the Virginia Beach oceanfront, can easily justify the economics of beach management because a significant portion of the City's revenues is directly related to tourism. In 1998, an estimated 1.7 million visitors recreated along the Virginia Beach oceanfront and spent more that $340 million (Department of Conservation and Recreation, 2000). Other large municipalities along the Chesapeake Bay, such as Norfolk, Newport News, and Hampton have a more difficult time justifying the expense of beach management practices due to the overall lack of revenues generated by the beaches. Within these municipalities, there are only a few hotels or other commercial ventures that directly depend on the beaches for income. Most of the public beaches are associated with small parks and recreational areas and the remainder of the shoreline is privately owned. Single and multi-family housing along sandy beaches generally provides some of the highest residential real estate in each municipality. Real estate taxes from residential properties alone, however, do not typically support the excessive cost of management practices. As a result, the beaches do not produce a significant portion of the annual revenues, making it difficult to justify maintenance and improvements solely on economics.

7.1 Quality of Life

There are several ways to describe "quality of life" when referring to beaches and shorefront property. For this Plan, the Beaches Committee determined that recreation, water quality improvements, wildlife habitat, aesthetics and education were important to the citizens of Hampton.

7.1.1 Recreational Beach Use

The Hampton shoreline supports three public beaches including Buckroe Park, Salt Ponds and the Grandview Nature Preserve. Salt Ponds provides a public beach with an access point, but very limited parking. As a result, beach use is primarily associated with the neighboring Salt Ponds community. The Nature Preserve is a passive, low-density recreational area located at the northernmost extent of the Hampton shoreline. Parking and access is provided at the Preserve, but the walk to the beach is somewhat lengthy and not particularly convenient for families with children. As a result, the most widely used public beach is at Buckroe.

The public beach at Buckroe provides convenient parking, restrooms, picnic tables, vending, lifeguard services during the summer months, and other recreational activities. In July, 1998 an estimated 8,000 to 10,000 people visited Buckroe Beach each week. Approximately half of the visitors were not residents of Hampton (Department of Conservation and Recreation, 2000). This would suggest that a significant number of locals utilize the beach during the summer, but that there is also a draw to neighboring cities. This is most likely due to the condition of the maintained beach and amenities. Considering that the public beach is less than 3/4 of a mile in length, this level of use constitutes this park as a high-density recreational area during summer months. Many residents utilize the beach and boardwalk for exercise and relaxation during the spring and fall months, as well. Beach counts conducted by Parks and Recreation show that the number of visitors has significantly increased since the beach was renourished in 1990, 1996 and 2005.

The number of residents and visitors that enjoy Buckroe Park is a strong statement as to its importance to the community. Other indicators that further support local quality of life issues include the importance or value of the public beach to its neighborhood. The Buckroe Neighborhood Plan has sited both maintenance and recreational improvements to the beach as neighborhood priorities. More recently, the “Friends of Buckroe Beach Park” have organized a non-profit group to establish playground facilities and other recreational amenities at Buckroe Park.

7.1.2 Natural Resource

Evaluating the beach as a natural resource is another quality of life issue that is difficult to assess quantitatively. Wide, sandy beaches help improve water quality by providing a natural buffer for pollutant removal from stormwater runoff. It also helps reduce damages from coastal storms. Shoreline areas that are properly stabilized can reduce siltation from the upland areas into the coastal waters, but do not provide the same pollutant removal benefits as a sandy beach.

Additionally, beaches provide habitat for several species of migratory birds and resident wildlife. The Grandview Nature Preserve is a premier example of a natural coastal spit. It is an undeveloped, low profile barrier beach that is backed by marshlands and has been designated as a Coastal Barrier Resources Act (COBRA) “Otherwise Protected Area” by the federal government. Two federally threatened species, piping plovers (Charadrius melodus) and the northeastern beach tiger beetle (Cicindela dorsalis dorsalis) are known to occur on the Preserve. In 1997, it was overtopped during high tides and in 1998 the twin nor’easters completely breached the barrier spit. Grandview Nature Preserve offers a more passive recreational experience for those who are primarily interested in viewing wildlife, bird watching and solitude. There is also local historical significance at this site, as it once supported the Old Point Comfort Lighthouse. The lighthouse was destroyed as a result of erosion and storm impacts, but a portion of the base material can still be seen at “Lighthouse Point.” Additionally, Grandview Nature Preserve, as well as other sections of the shoreline, including White Marsh provides excellent educational opportunities for understanding and observing natural shoreline dynamics and coastal ecosystems.

The proper management of the Hampton shoreline is an investment in the preservation of active recreational areas, as well as wildlife and waterfowl habitat, history, educational opportunities and aesthetics. Quality of life cannot be measured quantitatively but is vital to the overall health of the city.

7.2 Flood Damage Protection

Beach management practices can significantly reduce damages from storms. As the water level rises, not only are low lying areas flooded, but the waves generated by storms can propagate further inland resulting in a larger area of impact and higher water. A wide beach planform provides a buffer for the upland areas by causing waves to break and release their energy across the wide beach. An example would be the damages resulting from Hurricane Isabel in 2003. The low lying areas flooded throughout the City and those beachfront areas without a wide protective berm, including the north end of Malo Beach and Grandview, also suffered significant damage from wave impacts. Without the protective berm and the deeper foreshore along Grandview, storm waves broke directly on the revetment hurling one to two ton stone and concrete block through homes. Conversely, along the public beach at Buckroe, while flooding did occur, the bulkhead, streets, and condominiums did not experience the same level of impact as Grandview.

It is important to note, however, regardless of beach management practices, flooding did occur during Hurricane Isabel, and has continued to occur during high water events. The bulkhead, the wide sandy beach, the breakwater, and the existing groin field did not stop the rising water along Buckroe from entering homes and flooding streets. The majority of Hampton, including the tidal areas of Back River, Hampton River and Newmarket Creek, as well as Hampton Roads and the Bay fronting shoreline significantly flooded during Isabel and again during the November 2009 northeaster. In Hampton, it is not possible to stop coastal flood waters since the source of the rising water is the Atlantic Ocean and the Chesapeake Bay. Bulkheads and revetment can protect property in some areas, but due to the inherent tidal nature of Hampton, flanking will occur at some point.

At this time, the best way to reduce flood damages is to account for rising sea level and high water events in future development requirements, raise the base level of homes where applicable, and where possible design bulkheads and revetment at an appropriate elevation to account for high water and to prevent flanking. Wide beach areas and living shorelines do reduce some of the flooding impacts by reducing the wave impact and thereby reducing the additional wave induced water levels.

8.0 PLAN IMPLEMENTATION

This section on implementation has been provided to suggest some means to assist with project funding or mechanisms to reduce project costs in order to meet the plan goals. Other than limited funding through the Chesapeake Bay Trust to support the Living Shoreline initiatives, there are not any current state funds dedicated to beachfront management. The City currently partners with the Corps of Engineers for federal participation in beach renourishment at Buckroe. No other reaches of shoreline qualified for federal funding.

8.1 Funding Alternatives

The City should stay current on future legislation to determine the applicability for funding of beachfront projects. At this time, public funding alternatives are almost non-existent. At one time, the Department of Conservation and Recreation, Board on Public Beaches would offer matching grant funds for public shoreline projects in the Commonwealth. The 1990 and 1995 beach renourishment projects, as well as the Buckroe Avenue breakwater and Phase I of this study were all supported through matching grant state funds. The Public Beach Board is no longer active and has not offered state grants for nearly ten years.

Federal funding is also limited. Very few municipalities have been able to qualify for a federal storm damage reduction project. The City should continue to partner with the Corps of Engineers on the Storm Damage Reduction project at Buckroe Beach. The best chance for additional funds to support beach renourishment and shoreline protection projects is to lobby the state and federal legislature for new or dedicated funds.

8.2 Best Management Practices

Several goals or management practices have been identified to reduce the overall construction costs during implementation of the Management Plan. These practices include a sand source search, performance monitoring, project partnering, increasing the amount of public shoreline, and community enhancement through public/private partnerships.

8.2.1 Sand Source Search

The availability and location of a suitable sand source is the primary requirement for beach renourishment. Currently, the City relies on the sand reserves at Horseshoe Shoals for its beach renourishment program. The Corps of Engineers has also continued to examine Horseshoe Shoals as the primary source for the federal projects at Buckroe. Although Horseshoe Shoals is an excellent sand source, there are several issues associated with the site that elevate the cost of borrowing from this source. First, continued use of Horseshoe Shoals requires additional benthic and biological monitoring. Secondly, there are several deposits of ordnance in the borrow area that require special screens and safety intervention techniques to prevent them from being pumped to the beach. Finally, Horseshoe Shoals is approximately two miles from the shore in an exposed part of the Bay. As a result, only larger, more expensive dredges are capable of working in that area. These issues increase the cost of dredging for beach renourishment projects. In fact, the estimated cost for sand from Horseshoe Shoals has more doubled since 1990.

An important management practice would be to initiate a search for a closer and more reasonable sand source. A 1988 sediment study conducted by the Virginia Institute of Marine Science showed the possibility of beach quality sand off of Fort Monroe. There is a high probability of the existence of a sandy reservoir since that area appears to be a sink for much of the littoral transport along the Hampton shoreline. If the sand is good quality and there are no other restrictions (i.e. ordnance, conduits, cables, etc.) then sediment mining would be much less expensive than along Horseshoe Shoals.

Dredging deposition basins at Salt Ponds Inlet could also provide additional material for smaller projects along the shoreline. The use of pump out barges would be the most feasible means to dredge the basins and then transport the material to locations along the shoreline that would benefit from a smaller volume of sand. This might be feasible for areas along Reaches 3, 6, 7 and the north end of 8.

The cost for a sand search study would vary depending on the size and scope of the project. If a study were limited to approximately 60 core borings within a 2-mile radius of the Hampton shoreline, then the study cost would be in the range of $350,000. The long-term benefits of finding an alternative site to Horseshoe Shoals would significantly exceed the cost of the study.

8.2.2 Performance Monitoring

Project performance monitoring is an extremely important component in beach management. Monitoring data provide a record of beach condition through time. They can be used to identify critical areas, as well as evaluate the effectiveness of existing shoreline management practices. Monitoring results are often required as part of the documentation for new regulatory permits and are vital in research and development, as well as project design. Shoreline monitoring typically entails a routine collection and analysis of data that describes the condition of the beach through time.

Aerial photography is a combination of qualitative and quantitative data collection. It is a relatively inexpensive monitoring method and shoreline coverage can be extensive during a small segment of time. Vertical photography can be used to identify structures and their locations, sediment transport patterns, as well as shoreline position. If flown, photographed and processed correctly, aerial photography can provide a relatively accurate location of coastal features to develop a quantitative data set for comparison with other types of monitoring data. The drawback to aerial photography is that it can provide some information on the shoreline position, but does not provide much information on beach volume or changes below the water level.

Physical beach and offshore surveys are currently the most common and accurate quantitative method of data collection. When surveyed during consistent intervals through time, comparative beach profiles document patterns of shoreline and volume change. This information is extremely useful in comprehensive beachfront management and improving coastal engineering. Additionally, profiles are required for most project designs prior to construction. Offshore surveys also document the sediment "closure" envelope. Landward of closure, the sand is still active within the nearshore system, and moves between the offshore bar and berm system with the changing wave climate. Sediment located seaward of closure is often considered a sink to the nearshore system. Therefore, the overall sediment volume landward of closure should be conserved when possible to support a stable beach system. The drawback to a monitoring scheme utilizing physical beach surveys is that it can be relatively costly and each profile only provides information at a specific location. In order to comprehensively quantify an area, additional profiles are required at regular spatial intervals. The more profiles, the higher the monitoring cost. Assuming there are 25 profile locations extending from Fort Monroe to Lighthouse Point, the estimated cost for a single comprehensive beach and offshore survey would range between $15,000 and $20,000.

8.2.3 Project Partnering

Project partnering is a management tool that involves communication and planning (timing) to reduce overall project costs and create a more favorable bidding climate. The City of Hampton should closely track the shorefront construction of other municipalities and government projects. In many instances, construction timing along the beach is not always on a critical path. When feasible, municipalities and other governmental organizations should attempt to work together on construction timing to reduce mobilization/ demobilization costs in order to obtain the best prices. Contractors can provide more competitive bidding when several jobs are constructed in the same area. Project partnering applies to both dredging and disposal projects for beach renourishment, as well as other types of marine construction including breakwaters, jetties, revetments, etc. Since this management tool relies primarily on communication and cooperation, there is no set cost for implementation of this management practice. The realized construction savings could range from tens to several hundred of thousand dollars depending on the scope of the project.

8.2.4 Increasing Public Shoreline

Currently, the only non-Federal, public shoreline in the study area includes Buckroe Beach, Salt Ponds Beach, and Grandview Nature Preserve. Buckroe Beach is the most actively used shoreline. Grandview Nature Preserve is a low density, passive recreational area, while Salt Ponds offers limited public access and caters primarily to the Salt Ponds private community.

Therefore, increasing the amount of public shoreline provides additional funding opportunities for project implementation and can potentially reduce overall project costs. Obtaining public easements along the private sections of Buckroe and Thimble Shoals Court will continue to be problematic. These homeowners should be informed of management issues regarding the shoreline and encouraged to participate in public projects. Private property owners along White Marsh and Grandview, however, may be more acceptable to easement acquisition for either tax relief or the potential for a beach renourishment project along their eroded shoreline.

Public easements along private property will be necessary for beach renourishment projects and possibly any structural alternative designed to stabilize the shoreline. Without easements, all property owners will have to agree to project placement and design in order to obtain the necessary permits prior to construction.

8.2.5 Public/Private Partnerships

Development of public/private partnerships refers to "planning" issues which would promote growth and redevelopment along Hampton's shoreline. Many of these recommendations are documented The primary focus area would be the Buckroe Beach neighborhood where there is a large potential for light commercial, retail and restaurant venues, as well as residential redevelopment. The results of the 2001 beach survey conducted during Labor Day weekend at Buckroe Beach showed that most of users wanted more retail stores and restaurants closer to the beach and would spend several dollars per person during their stay for such amenities. Additionally, a well-planned retail/restaurant development would enhance the overall characteristic of the area and potentially spark residential redevelopment.

9.0 RECOMMENDATIONS

The following list provides the summary of the final recommendations or plan goals for the Hampton Beachfront Storm Protection and Management Plan. In order to implement the goals, it is recommended that the City of Hampton continue lobbying for state and federal funds to offset municipal costs for project construction and management. The City should also encourage acquisition of property and easements for public access. The more shoreline in the public domain increases the potential for funding and the more extensive the project, the higher likelihood of long term success. Other management practices include continued project monitoring in order to design and construct effective projects, a search for a more economic sand source, project partnering to reduce construction costs, and promoting public/private partnerships to encourage redevelopment along the Buckroe corridor. The estimated costs, with the exception of Reach 8, are for initial construction costs only. Maintenance cycles have not been evaluated at this time since the frequency of renourishment would depend on the implementation.

- **Fort Monroe – South**
  - Fort Monroe has a management plan for the shoreline. A portion of it has been constructed. Future management/ownership of Fort Monroe will dictate shoreline management practices.

- **Fort Monroe North through Buckroe Beach (Reaches 1 and 2)**
  - Continue with federal project participation at Buckroe Beach.
  - Obtain easements along Thimble Shoals Court to allow for a continuous renourishment project . (This plan does not currently include renourishment for Thimble Shoals Court or Fort Monroe since there is no municipal jurisdiction and they are at the terminus of the management area.)
  - Construct a terminal breakwater at the northern end of Dog Beach / southern end of Thimble Shoals Court.
  - Construct 200 ft of beach renourishment with 50 ft of advance maintenance along Reach 2, with the understanding that Reach 1 could possibly be included in the future as a betterment to the federal project.

  Estimated cost for Reaches 1 and 2 is $1,665,000 (not including easement acquisition and assuming a 50/50 cost share with the federal government for renourishment at Buckroe Beach). The cost estimate also assumes that all three breakwaters in Reach 2 have been constructed.

- **Malo Beach - (Reach 3)**
  - Obtain easements along private property to allow for renourishment and/or breakwater construction.
  - Acquire available property for future public access to the beach.
  - Construct up to two breakwaters to help reduce littoral transport.
  - Construct a 200 ft beach renourishment with 50 ft of advance maintenance (if easements have been obtained).

  Estimated cost for Reach 3 is $3,585,000 (not including easement acquisition.)

- **Salt Ponds Beach - (Reach 4)**
  - Make improvements to the Salt Ponds Inlet infrastructure. Engineering studies will need to be approved prior to any specific recommendations.
  - Construct a breakwater at the southern end of the beach.
  - If improvements are made to the inlet, continue to renourish the beach, otherwise continue to bypass sand from inlet maintenance dredging.
  - Dredge sand traps on both the north and south ends of the inlet and use that material to renourish various public sections of the shoreline.

  Estimated cost for Reach 4 is $4,650,000. (Assumes that improvements will be made to Salt Ponds Inlet with a budget of $2,500,000.)

- **White Marsh - Private (Reach 5)**
  - Obtain easements along private property to allow for renourishment and/or breakwater construction.
  - If improvements are made at the inlet, and easements have been obtained, then construct a 100 ft beach renourishment project with 50 ft of advance maintenance.
  - Construct up to two breakwaters to reduce littoral transport.
  - Dune enhancement (create a more substantial dune system if the beach is renourished), otherwise it would be appropriate to enhance the dunes with vegetation, as necessary.

  Estimated cost for Reach 5 is $3,000,000. (This estimate does not include the cost of easement acquisition and provides an $80,000 budget for dune enhancement plantings.)

- **Grandview - Private (Reach 6)**
  - Obtain easements along private property to allow for renourishment and/or breakwater construction.
  - Construct a 100 ft beach renourishment project with 50 ft of advance maintenance

- Construct up to three breakwaters to stabilize the renourishment project. The northern breakwater should be sited to also protect Hawkins Pond.

  Estimated cost for Reach 6 is $4,750,000. (This estimate does not include the cost of easement acquisition.)
-

- **Grandview Nature Preserve - South (Reach 7)**
  - Add limited renourishment at the southern end to help protect Hawkins Pond from additional breaching and maintain sediment within the system.
  - While not modeled in this study, an anchoring breakwater at Lighthouse Point may be appropriate if renourishment has been added to the south at Grandview.
  - Construct a dune restoration and enhancement project, as needed.
  - A geotube base to a dune restoration may be appropriate in the vicinity of Hawkins Pond.

    Estimated cost for Reach 7 is 1,250,000. This cost includes a budget for limited beach renourishment, a breakwater at Lighthouse Point and dune enhancement.

- **Grandview Nature Preserve – North (Reach 8)**
  - Continue renourishment at the site of the breach restoration, as needed.
  - Dune restoration and enhancement, as needed.

    Estimated cost for Reach 8 is $1,000,000 which reflects maintenance costs since the project has already been constructed. This amount will probably be required during the planning implementation phase to renourish and/or restore the dunes.

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